COURSE IN

Pharmaceutical and Chemical Arithmetic

J. W. STURMER

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INCLUDING

WEIGHTS AND MEASURES

BY

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FOURTH EDITION
WITH ANSWERS

PUBLISHED BY THE AUTHOR
1922
PRICE $1.75

PREFACE TO THE FOURTH EDITION.

The preceding editions having been welcomed so heartily, the writer deems a radical change in the arrangement or in the scope of the COURSE unnecessary, and no such change has been made in this revision. The advent of a new pharmacopoeia has, however, necessitated a large number of minor changes.

A short presentation of volumetric calculations has been added; but discussions on intricate volumetric processes—even though these determine the procedure in calculating the results—are considered beyond the scope of this volume.

The first four chapters appear elementary, from an arithmetical standpoint. And so they are. But the experience of teachers, of members of boards of pharmacy, and of practical pharmacists, has proven that, notwithstanding the adoption of the higher entrance requirements by the colleges, instruction covering the ground of these chapters is as necessary to-day as it was in former years.

As in the preceding editions, so also in this, the writer has avoided the presentation of a multiplicity of rules and mathematical formulas. Indeed, with exception of the arbitrary rule for calculating the doses for children, and the rule concerning the Beaumè hydrometer scales, no rules are given which the student is not taught to deduce from solutions of problems in the text.

In this edition ANSWERS are given for a sufficient number of problems throughout the COURSE, so that students studying without the aid of a teacher may be able to note their progress. But at the request of instructors who use the book in their classes, some problems are left unanswered.

It should be stated that some of the answers given are only approximately correct, as in some instances fractions were "rounded off" to shorten the calculations.

JULIUS WILLIAM STURMER.

CONTENTS.

CHAPTER I.

WEIGHTS AND MEASURES

A.—The Metric System.

The most important feature of the metric system is that the units of each of its branches are in decimal progression. Ten of any unit make one of the next higher, ten of which in turn make one of a still higher value; etc. The system thus is in conformity with our arithmetical notation; and denominate numbers in metric units can be added, subtracted, multiplied, and divided as readily as abstract numbers. In this lies the chief practical advantage of the metric system over the other systems in vogue.

The branches of the metric system are: (1) linear measure, (2) surface measure, (3) cubic measure (dry measure), (4) cubic measure for liquids (volume measure), (5) and weight.

The relationship between these branches is a very simple one—a fact constituting the second great advantage of this system of weights and measures. The primary unit of linear measure—the *Meter*—is the basis of the entire system. Thus, the primary unit of surface measure, called *Are,* is the square of ten Meters. The primary unit of cubic measure (dry), the *Stere,* is the cube of one Meter. The primary unit of volume measure, the *Liter,* is the cube of one-tenth of a Meter. And the primary unit of weight, the *Gramme,* is the weight of a cubic $\frac{1}{100}$ Meter* of water, at its greatest density, and weighed in vacuo.

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*Their relationship has been slightly altered by inaccuracy in the weighings made when the first metric weight was constructed. See page 12.

For convenience in measuring, secondary units, some larger, and some smaller than the units already referred to, were established. These secondary units, as has been stated, differ from each other by ten or by some power of ten. The names for the secondary units are formed by joining certain Greek and Latin prefixes—Greek for multiples, Latin for the fractionals—to the name of the unit itself.

The prefixes used are:

Latin	**milli**	**= thousandth ($\frac{1}{1000}$)**
	centi	**= hundredth ($\frac{1}{100}$)**
	deci	**= tenth ($\frac{1}{10}$)**
Greek	**Deka**	**= ten (10)**
	Hecto	**= hundred (100)**
	Kilo	**= thousand (1000)**
	Myria	**= ten-thousand(10000).**

Thus we have *milli*meter, *milli*liter, *milli*gramme; *centi*meter, *centi*liter, *centi*gramme; etc.

Rules for capitalizing names of units.—The names of the primary units—Meter, [Are, Stere], Liter, Gramme—are usually written with a capital, as are also the names of the secondary units larger than the primary ones; but the names of the units smaller than the primary units are written with a small initial letter. Examples: *Deka*meter, but *deci*meter; *Myria*gramme, but *milli*gramme. These rules, as will be seen, serve to decrease the similarity in appearance between the names of certain multiples and certain fractionals. However, the rules are not universally observed, and in many scientific works the names of all units are written with small initial letters.

Abbreviations.—The abbreviations for primary units are: Meter = M; Liter = L; Gramme = Gm.

The abbreviations for the prefixes are:—milli = m; centi = c; deci = d; Deka = D; Hecto = H; Kilo = K; Myria = M.

To construct the abbreviation of any secondary unit, the abbreviation of the prefix is coupled with the abbreviation for the primary unit. Thus Kilometer = Km.; millimeter = mm; millilitei = ml.; centigramme = cgm.; etc.

However, in case of abbreviations of secondary units of weight the final *m* is frequently omitted. See table on page 13.

The rules given for capitalizing names of units apply likewise to their abbreviations; Dm. being used for Dekameter, dm. for decimeter, Mgm. for Myriagramme, and mgm. for milligramme. But in the U. S. Pharmacopœia the term mil, plural mils, is used in place of ml. In the preceding edition of the Pharmacopœia (U. S. P., VIII) the mil was called the cubic centimeter, abbreviated c.c., this latter term being still in general use in chemical literature. The mil is not capitalized. The mil and the c.c. are used interchangeably in the succeeding pages.

1. Linear Measure.

The primary unit of length, the Meter, may be defined as the $\frac{1}{40,000,000}$ of the earth's circumference, measured across the poles. The distance from the equator to the north pole was calculated from surveys made along the meridian which passes through Paris; and this distance, divided by 10,000,000, was chosen as the unit of length.*

Note.—It is deemed desirable that a system of measure be based upon some unalterable object in nature, in order that the correctness of the measures accepted as models may be redetermined, should this become necessary. The metric system is based upon the dimensions of the earth—an object ill adapted for a "natural standard;" first, because the earth is not absolutely unalterable in size, and second. because of the difficulty of obtaining the measurement. A far better "natural standard" is the second's pendulum, upon the length of which the English measure is now based. See page 22.

*According to recent measurements the earth's quadrant measures 10,000,880 Meters, showing that a slight error had been made in the original measurements, and that the unit now in use is a trifle shorter than the meter required by theory.

Table of Linear Measure.

Table A.

10 millimeters (mm.) = 1 centimeter (cm.)
10 centimeters = 1 decimeter (dm.)
10 decimeters = 1 Meter (M.)
10 Meters = 1 Dekameter (Dm.)
10 Dekameters = 1 Hectometer (Hm.)
10 Hectometers = 1 Kilometer (Km.)
10 Kilometers = 1 Myriameter (Mm.)

For miscroscopic measurements the micro-millimeter, which is $\frac{1}{1000}$ of a millimeter, is used. It is usually written micron or mikron, and abbreviated mkm.

Table B.

Kilometer	*Hectometers*	*Dekameters*	*Meters*	*decimeters*	*centimeters*	*millimeters*
1 =	10 =	100 =	1000 =	10000 =	100000 =	1000000
	1 =	10 =	100 =	1000 =	10000 =	100000
		1 =	10 =	100 =	1000 =	10000
			1 =	10 =	100 =	1000
				1 =	10 =	100
					1 =	10

Units in Common Use.—Units larger than the Meter are seldom employed in pharmaceutical literature. As has been stated on page 9, the U. S. Pharmacopœia ignores the larger units, and in its text mm. and cm. are capitalized without danger of ambiguity.

2. SURFACE MEASURE.

3. CUBIC MEASURE FOR SOLIDS. [DRY MEASURE.]

These two branches of the metric system are not used in pharmacy; hence are here omitted.

4. CUBIC MEASURE FOR FLUIDS. [VOLUME MEASURE.]

For a primary unit of volume the cube of $\frac{1}{10}$ Meter was

selected, and was named Liter [pronounced Leeter, not Laiter.]* But the present Liter is the volume of 1 Kg. of water, at 4°C., and under standard atmospheric pressure.

Tables of Volume Measure.

Table A.

10 milliliters (mils) = 1 centiliter (cl.)
10 centiliters = 1 deciliter (dl.)
10 deciliters = 1 Liter (L.)
10 Liters = 1 Dekaliter (Dl.)
10 Dekaliters = 1 Hectoliter (Hl.)
10 Hectoliters = 1 Kiloliter (Kl.)
10 Kiloliters = 1 Myrialiter (Ml).

The milliliter (mil) is also called cubic centimeter, to which it bears the same relation that the Liter bears to the cubic decimeter. The abbreviation for cubic centimeter is c.c., c.cm., or, as in the old U. S. P., Cc.

Table B.

Myrialiter	*Kiloliters*	*Hektoliters*	*Dekaliters*	*Liters*	*deciliters*	*centiliters*	*milliliters*
1 =	10 =	100 =	1000 =	10000 =	100000 =	1000000 =	10000000
	1 =	10 =	100 =	1000 =	10000 =	100000 =	1000000
		1 =	10 =	100 =	1000 =	10000 =	100000
			1 =	10 =	100 =	1000 =	10000
				1 =	10 =	100 =	1000
					1 =	10 =	100
						1 =	10

Units in Use.—In pharmaceutical and chemical works only two units are commonly used: the Liter, and the milliliter, which latter, however, is called the mil or the cubic

* The more refined methods of weighing and measuring of recent investigators have brought to light the fact that the Liter in actual use differs slightly from the Liter required by theory.

centimeter. The table of volume measure, as actually used is therefore very simple; namely

1000 mils (cubic centimeters) = 1 Liter.

However, in books and periodicals the other units are *sometimes* met with, and therefore should not be overlooked by the student.

5. WEIGHT.

The primary unit of weight, the Gramme, is defined as the weight of one mil of water, at 4°C., and under standard atmospheric pressure.*

In pharmacy the name of the primary unit of weight is always spelled according to French orthography—*Gramme.* The English spelling, *gram*, gives to the word too great a similarity to the word grain—the name of a unit of weight of the Apothecaries' System of Weight. The pronunciation is *gram*, the *a* having the same sound as in Sam. The abbreviation is always capitalized, *Gm.*, lest it be mistaken for *gr.*, which is the abbreviation for grain.

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*Weight in a vacuum is called *true weight*, in contradistinction to *apparent weight*, which is weight obtained in air, i. e., under ordinary conditions.

Air, like water, though in a lesser degree, exerts a buoyant force on bodies; tending to lift or float both the body being weighed and the weights used. This buoyant force is exerted on a body in proportion to its bulk. Hence, if there is a difference in bulk between the body weighed and the weights used, there will be a corresponding difference in this buoyant force, and the weight obtained will not be truly proportional to mass.

It follows also that this difference in buoyant force will fluctuate with the density of the air, i. e., with the barometric pressure. For this reason the barometer reading is taken into consideration in weighings where great accuracy is required, and weighing in vacuo is impracticable. See page 31.

Recent determination of the weight of water under standard conditions, and with the most delicate balances, have shown that the original Kilogramme weight, which has served as the model for over 100 years, is about .58 Grammes too light to represent the weight of 1 cubic decimeter of water. The primary unit itself, the Gramme, is, therefore, .00058 Gm. or nearly .06 per cent. lighter than was intended. But as the units of volume were made correspondingly smaller, one milliliter (actual) being the volume of one Gramme (actual) of water, and one Liter (actual), the volume of one Kilogramme (actual), this error in the construction of the original Kilogramme weight has no practical bearing.

Table A.

10 milligrammes (mg.) = 1 centigramme (cgm. or cg.)
10 centigrammes = 1 decigramme (dgm. or dg.)
10 decigrammes = 1 Gramme (Gm.)
10 Grammes = 1 Dekagramme (Dgm. or Dg.)
10 Dekagrammes = 1 Hectogramme (Hgm. or Hg.)
10 Hectogrammes = 1 Kilogramme (Kgm. or Kg.)
10 Kilogrammes = 1 Myriagramme (Mgm.)

As already stated, the final *m* in these abbreviations is frequently omitted.

Table B.

Myria gramme	*Kilo grammes*	*Hecto grammes*	*Deka grammes*	*Grammes*	*deci grammes*	*centi grammes*	*milli grammes*
1 =	10 =	100 =	1000 =	10000 =	100000 =	1000000 =	10000000
	1 =	10 =	100 =	1000 =	10000 =	100000 =	1000000
		[illegible] =	10 =	100 =	1000 =	10000 =	100000
			1 =	10 =	100 =	1000 =	10000
				1 =	10 =	100 =	1000
					1	10 =	100
						1 =	10

Units in Common Use.—In prescriptions, and in the U. S. Pharmacopœia, only one unit of weight—the Gramme—is used. In many scientific books and periodicals the decigramme, centigramme, and milligramme are used in addition. The Kilogramme is used in commercial transactions, and is frequently abbreviated to *Kilo,* pronounced Killo, not Kailo.

Metric Prescriptions.

Rules.—1. All volumes should be expressed in cubic centimeters (milliliters = mils.), and all weights in Grammes.

2. Arabic numerals should be used in all cases; and the numbers should be placed before the abbreviations. Thus, 25 Gm., 160 Cc., 5 cm., etc.

3. Since so much depends upon the proper placing and the proper reading of the decimal point, special precautions should be observed to avoid a chance for a mistake. It is a common practice to draw a vertical line in the proper place on the prescription blank, and to write whole numbers of

mils (c.c.) or of Grammes to the left of the line, and the fractions beyond the line. Thus the decimal point is done away with.

Example.—

℞	Quin. sulph.	2	
	Ferri phos.	8	75
	Potass. citr.	8	75
	Syr. calc. lactophos.	125	
	Aquae	15	
	Elix. Arom. q. s. ad	500	

Since it is customary in this country to prescribe all liquids by measure, and all solids by weight, there is no difficulty in determining which numbers in a prescription stand for mils (c.c.), and which for Grammes. Quinine sulphate being a solid, the "2" following this item in the prescription given, stands for 2 Gm. But the "125," expressing the quantity of the syr. calcium lactophosphate, obviously means 125 mils; for the article is a liquid, and hence is to be measured.

If the vertical line is not made use of, every decimal fraction in the prescription should be written with a cipher before the decimal point. Thus, 0.75 Gm. in place of .75 Gm.; 0.1 mil in place of .1 mil. This precaution makes it less probable that imperfections in the paper, or accidental markings, be mistaken for decimal points. The older practice of using a comma (,), in place of a point, is also to be recommended. However, the best safe guard is in the use of the vertical decimal line.

Reading Metric Quantities in Prescriptions.—A whole number expressing a metric quantity is always read as a simple denominate number, and not as a compound number; that is, only one unit is used, no matter how large the number. Thus, 3450 Gm. is read—three thousand four hundred and fifty Grammes;—not three Kilogrammes, four Hectogrammes, and five Dekagrammes, which would be unnecessarily cumbersome. 6565 Cc. is read—Six thousand five

hundred and sixty-five cubic centimeters—not six Liters, etc., etc.

Fractions of mils (c.c.) are read as tenths or hundredths, as the case may be. Fractions of Grammes are read as so many of the lowest unit in the fraction, it being remembered that the first decimal place belongs to decigrammes, the second to centigrammes and the third to milligrammes. According to this rule 0.5 Gm. would be five decigrammes; 0.55 Gm., fifty-five centigrammes; 0.555 Gm., five hundred and fifty-five milligrammes. In case of a fourth decimal, this is read as so many tenths of milligrammes; and .3575 Gm., as three hundred and fifty-seven and five-tenths milligrammes.

Some pharmacists ignore the units, decigramme and centigramme, and read all fractions of grammes as milligrammes. Thus 0.5 Gm. would be five hundred milligrammes, and 0.55 Gm., five hundred and fifty milligrammes.

In dictating prescriptions by telephone, especially if there are mixed decimals to dictate, the plan of reading the numerals from left to right (in place of the whole numbers) should be adopted. The pharmacist can then copy the numerals as fast as read, and need not hold the entire number in his mind—a task which is very trying, and may lead to error.

To illustrate: the prescription—

℞	Arsenous acid	.065
	Ext. opium	.48
	Quinine sulphate	8.75
	Make 65 pills.	

Should be telephoned—

Arsenous acid—point—nought—six—five,
Ext. opium—point—four—eight,
Quinine sulphate—eight—point—seven—five.
Make 65 pills.

Of course *Grammes* would be understood.

Metric Prototypes.

As has been stated, the metric system was based on the $\frac{1}{10000000}$ of the earth's quadrant. A bar of platinum was constructed of this length, and was deposited in the French Archives, to serve as a prototype or model for the meter measures intended for actual use.

There was also constructed, and deposited in the French Archives, a weight of platinum of such size as to counterpoise in vacuo one cubic decimeter of water at its greatest density. This weight constituted the fundamental standard of mass, and was to serve as a prototype or model for the Kilogramme weights (and indirectly for the other metric weights) intended for actual use.

The metric system was adopted by France in 1795. The prototypes referred to became the legal reference standards of France shortly after the adoption of the system.

In 1875 an International Metric Convention was held in Paris, the United States participating. This convention called into being an International Bureau of Weights and Measures, the first duty of which bureau consisted in preparing an international standard Meter bar, and an international standard Kilogramme weight, and duplicates of these for the seventeen countries which had contributed to the support of this bureau.

It was decided that the international prototypes and their duplicates should be made to equal (the Metric bars in length, and the Kilogramme weights in mass) the prototypes of the French Archives; and should be constructed of an alloy of 90 parts of platinum and 10 parts of iridium, a composition selected on account of its hardness and its resistance to the action of atmospheric gases.

Of the 30 Meter bars and 31 Kilogramme weights made, one Meter bar and one Kilogramme weight were selected as international prototypes and placed in the charge of the international bureau. The others were distributed among the countries which had called the bureau into existence. The distribution was effected by lot, the United States drawing Meters No. 21 and No. 27, and Kilogrammes No. 4 and No. 20.

Meter No. 27 and Kilogramme No. 20 were selected as our National Prototypes, and are carefully preserved in the United States Office of Weights and Measures, which is a branch of the Treasury Department. The Meter No. 21 and the Kilogramme No. 4 are used as working standards.

While the 30 Meters and the 31 Kilogrammes were made as nearly alike as it was possible to make them, it was found that they were not precisely alike. But the difference between the International Prototypes and the several national prototypes was in each case determined with the utmost care. Thus our Na-

tional Kilogramme (No. 20) was found to be .00003 Gm. too light; and this fact must be taken cognizance of in the standardizations of other weights.

The two National Prototypes—the Meter No. 27 and the Kilogramme No. 20—are at the present time the ultimate reference standards for all weights and measures in use in the United States, with the sole exception of the weights used in the U. S. mints, which weights are by law still referable to the standard troy pound received from England in 1827.

Advice to the Student.

The student is advised to acquaint himself with the metric length units by the use of a metric rule; with the volume units by means of measuring vessels graduated in mils (c.c.) and Liters; with the units of mass, by means of a set of metric weights. The Gramme and the mil (c.c.) should be known to the pharmacist as the pound and pint are known to the grocer—from actual use of the weights and measures. It is a mistake to think of the Liter as equivalent to so many fluid ounces, and of the Gramme as so many grains. Such equivalents have their uses; but the student must become familiar with the metric units by using measures and weights;—not through equivalents. To learn French properly, one must learn to *think* in French—not to think in English and then to translate. In like manner, one must learn to *think* in metric units—to guess at the diameter of a filter in centimeters, the capacity of a flask in cubic centimeters, the weight of a mass of quinine in Grammes. As long as the metric units are abstract ideas, the metric system will appear intricate and hard to master; but when these units find expression in something material—in graduated measures and sets of weights—all difficulty disappears at once.

Problems and Exercises

1. Read the following metric expressions: (a.) 6560 c.c.; (b.) .02 L.; (c.) 2 L. expressed in mils; (d.) 1.645 Gm.; (e.) 65 mg.; (f.) 6 cg.; (g.) 6 dg.; (h.) 6 Kg.; (i.)

6 Kilo.; (j.) 17 M.; (k.) 7 cm.; (l.) 700 mm.; (m.) 6789.123 M.; (n.) 6789.1 c.c.; (o.) 6789.123 Gm.

2. Write in numbers, followed by the proper abbreviations:—(a.) six milligrammes; (b.) sixteen centigrammes; (c.) six tenths milligrammes; (d.) six Liters; (e.) six and six tenths milliliters; (f.) six and six tenths cubic centimeters; (g.) six hundred milligrammes.

3. By moving the decimal point read—(a.) 6000 c.c. as L.; (b.) 1455 Gm. as Kg.; (c.) 414 mm. as M.; (d.) .45 Gm. as cg.; (e.) .45 Gm. as mg.; (f.) 40 mg. as Gm.; (g.) 4 dg. as mg.

4. Supply the proper abbreviations in the following formula:—

Guaiac	12	5
Potass. carbonate		6
Pimenta	3	
Pumice	6	
Alcohol	43	5
Water	43	5
Diluted alcohol q. s. ad	100	

Addition.

5. Add: 2Kg., 43 Gm., 42 cg., 425 mg.

Solution.— 2 Kg. = $2 \times 1000 =$ 2000 Gm.
43 Gm. = 43 "
42 cg. = $42 \div 100 =$ .42 "
425 mg. = $425 \div 1000 =$ .425 "

2043.845 Gm.

Suggestion.—To simplify addition and subtraction, express all lengths in Meters, all volumes in mils (c.c.), all weights in Grammes. Then weights may be added to weights, volumes to volumes, and lengths to lengths, in the same manner in which abstract numbers are added.

6. Add: 10 L., 100 c.c., 5.6 L., 3.4 c.c. Ans. 15703.4 c.c.

7. Add: 2 Kg., 4 Dg., 500 Gm., 32 mg., Ans. 2540.032 Gm.

8. Add: 2 cm., 25 cm., 5 M., 500 mm., 13 Km.

9. Add: 5 cg., 50.5 mg., 5.5 Gm.

10. Add: 6 Kg., 20 Hg., 200 Dg., 2145 Gm. **Ans.** 12145 Gm.

Subtraction.

11. Subtract 345 c.c. from 5 L.

Solution.—5 L. = 5000 c.c.; and 5000 c.c. — 345 c.c. = 4655 c.c.

12. Subtract 345 mg. from 140.002 Gm.

Solution.— 345 mg. = .345 Gm.; and 140.002 Gm.— .345 Gm. = 139.657 Gm.

Subtract:

13. 1 cm. from 500 mm. Ans. 490 mm.

14. 2 L. from 6050 c.c. Ans. 4050 c.c.

15. 3.5 c.c. from 1 L. Ans. 996.5 c.c.

16. 1.4 mg. from 10 Gm. Ans. 9.9986 Gm.

17. A druggist making solution of lead subacetate finds that his evaporating dish plus contents weighs 757 Gm. The dish itself weighs 289.02 Gm. How much water must be added to make the contents weigh 500 Gm? Ans. 32.02 Gm.

Multiplication.

Remarks.—The product is always in the same unit [denomination] as the multiplicand. If mg. are multiplied, the product will be mg.; if Gm. are multiplied, the product will be Gm.; etc.

If a length, volume, or weight is expressed in a compound denominate number—that is, if several units are used in expressing it—reduce to a simple denominate number before multiplying.

Remember that the decimal places in the product must equal the total number of decimal places for both factors.

That is, if the multiplicand has 3 decimals, and the multiplier 4, the product must have [3+4 =] 7.

18. Multiply 5.045 Gm. by .004.

Operation.—5.045 Gm.
× .004

.020180 Gm.

19. Multiply 345 mg. by 856. Ans. 295320 mg. = 295.320 Gm.

20. Multiply 50.5 c.c. by 7.058. Ans. 356.429 c.c.

21. A prescription is received for 48 capsules, each to contain .195 Gm. of mercurial mass, .12 Gm. of comp. ext. colocynth, .15 Gm. of ext. gentian. How much must be weighed out of each ingredient?

Division.

Remarks.—The quotient is always in the same unit [denomination] as the dividend.

Remember that the quotient must have as many decimal places as those in the dividend exceed those in the divisor. If the decimal places in the divisor exceed those in the dividend, add ciphers to the latter until the decimal places equal those in the divisor.

When a denominate number expressing volume or weight is to be divided by another denominate number also expressing volume or weight, both must be in the same unit [denomination]. See prob. No. 27.

22. Divide 95.789 Gm. by 7.42.

23. Divide 74.2 mg. by .02. Ans. 3710 mg.

24. Divide .04 Gm. by 64.

25. Divide 6 Kg. by 8. Ans. 750 Gm.

Suggestion.—Since the number in the dividend in problem No. 25 is smaller than the number in the divisor, reduce to Gm. before dividing.

Remember that the quotient must have as many decimal places as those in the dividend exceed those in the divisor.

26. Divide 30 Kg. by 8. Ans. 3750 Gm.

Suggestion.—Since the number in the dividend cannot be divided by 8 without a remainder, it is simpler to reduce 30 Kg. to Gm. before dividing. It is not customary to express metric quantities by compound denominate numbers.

27. A Seidlitz powder contains 7.75 Gm. of Rochelle salt. How many powders could be made from 2 Kg. of the salt? Ans. 258.

Miscellaneous Problems.

28. A druggist receives four lumps of opium, weighing respectively (1.) 1 Kg. 20 Gm., (2.) 5 Hg. 3 Dg., (3.) 650.35 Gm., (4.) 205 Gm. 15 mg. How many Gm. of opium does he receive? Ans. 2405.365 Gm.

29. Suppose opium were worth $13.50 per Kilo. What would the above consignment cost? Ans. $32.47.

30. A certain elixir is to contain .175 mg. of strychnine in each c.c. How much strychnine must be weighed out for 3 L. of the elixir? Ans. 525 mg.

31. A certain prescription calls for 75 pills, each to contain 200 mg. of quinine sulphate. How much of the latter must be weighed out? Ans. 15 Gm.

32. A prescription calls for 5.1 Gm. of pancreatin, to be mixed with 20.4 Gm. of sodium bicarbonate, and the mixture to be divided into powders weighing 1.7 Gm. each (amount for peptonizing 500 c.c. of cow's milk). How many powders will the mixture make? Ans. 15.

33.	℞	Strych. sulph.		06
		Quin. sulph.	16	
		Ferri phos.	10	75

Mix and divide into 85 pills.

How much strychnine sulphate, how much quinine sulphate, and how much ferric phosphate in each pill?

34. A pharmacist extracts 7 headache tablets with chloroform, for the purpose of dissolving the caffeine present. He evaporates the chloroformic solution to dryness in a beaker, and finds that the residue and the beaker together weigh 11.005 Gm. The beaker itself weighs 10.38 Gm. How much caffeine in each tablet? Ans. .08928 Gm., which read, eighty-nine and twenty-eight hundredths milligrammes.

B. English Systems Customary in the United States.

While the metric system has had legal sanction since 1866, has since been adopted for all scientific work, and is the official system of our pharmacopœia, it has not as yet displaced the cumbersome English Systems in our every-day business transactions. Lumber is still sold by the foot, cloth by the yard, coal oil by the gallon, and meat by the avoirdupois pound. For prescription work the use of the old English troy weight—now obsolete in England—is still quite general in the United States.

1. Linear Measure.

The English linear measure, with its units of inch, foot, yard, etc., was originally derived from the average length of the barley corn. According to an English law of the year 1324, "three barley corns, round and dry, shall make an inch, and twelve inches a foot." But at the present time the inch is defined in England as the $\frac{1}{39.13929}$ of the length of the second's pendulum, which latter is therefore the natural standard of the English linear measure, and through the same, of all the English systems of measure and weight.*

*The length of a pendulum determines the time of its vibrations. The shorter the pendulum, the shorter are its vibrations; the longer the pendulum, the longer and slower are its vibrations. A pendulum 39.13929 inches in length will always make one complete vibration ("swing-swang") per second, provided the pendulum is placed in a vacuum, the temperature is 62 degrees F., the altitude is that of the sea level, and the latitude, that of London. Conversely, a pendulum, beating seconds of time under the aforementioned conditions is bound to be just 39.13929 inches in length. And since a second's pendulum can be constructed as often as necessary, it serves admirably as a natural standard,—i. e., as a check upon the material standards in use.

The lack of simplicity in the relationship between the inch and the length of the second's pendulum—the latter being 39.13929 times that of the former—is readily accounted for by the fact that the length of the inch had become fixed by custom and by law, before the second's pendulum was selected as the natural standard.

In the United States the inch is now defined as equivalent to 25.4001 millimeters.

The yard is defined as $\frac{3600}{3937}$ Meters.

All our measures and weights are now defined in metric terms, thus making the metric prototypes the standards for all the weights and measures in use in the United States, excepting weights used in the U. S. Mint, which are still regulated, in accordance with a law of Congress, by the standard troy pound, received from England in 1827.

To repeat:—the American and the British yard are identical in length; but the former has for its prototype the Meter bar No. 27 (see page 17) and for its natural standard, the earth's quadrant; while the British yard is referable to a certain bar, with a gold peg near each end, a bar deposited in the office of the Exchequer, London;—and the natural standard for the British yard is the second's pendulum.

Table A.

12 inches (in.) = 1 foot (ft.)
3 feet = 1 yard (yd.)
[Higher units are never used in pharmacy.]

Table B.

Yard		*Feet*		*Inches*
1	=	3	=	36
		1	=	12

2. Apothecaries' Fluid Measure (U. S. Wine Measure).

The primary unit of the U. S. Wine Measure is the gallon, which is defined by the National Office of Weights and Measures as the volume of 3785.33 mils or 3785.33 Gm. of pure water.

Prior to 1893 the gallon was officially defined as 231 cubic inches, which shows its relation to the English Linear measure.

The Wine Measure, as used in this country, with its units of gallon, quart, and pint*, was brought from England, in which country, however, it has long since (1826) been superseded by the Imperial Measure.

The Apothecaries' Fluid Measure is the Wine Measure minus the quart unit, and with the addition of three units smaller than the pint.

The table, giving symbols and abbreviations, is as follows:

Table A.

60 minims (♏)	=	1 fluid drachm (f℥)
8 fluid drachms	=	1 fluid ounce (f℥)
16 fluid ounces	=	1 pint (O.)
8 pints	=	1 gallon (Cong.)

O. is the abbreviation for the Latin word Octarius; Cong., for the Latin word Congius.

Table B.

Gallon		*Pints*		*Fluid Ounces*		*Fluid Drachms*		*Minims*
1	=	8	=	128	=	1024	=	61440
		1	=	16	=	128	=	7680
				1	=	8	=	480
						1	=	60

*The gill, which is ¼ pint, is obsolete, but is occasionally met with in old family recipes.

Apothecaries' Measure in Prescription Writing.—Roman numerals are used in connection with this system. It is customary to place the symbol or abbreviation before the number—not after it, as in case of metric prescriptions.

Example:

℞	Tinct. ferri chloridi	f ʒ vj
	Acidi phosphorici diluti	f ʒ iij
	Spiritus limonis	f ʒ ij
	Syrupi q. s. ad	f ℥ vj

Notes.—The dot over the numeral I is used as a precaution against ambiguity which might be occasioned by carelessness in writing. For example, ij might stand for II or for V; but if the dots are systematically used, their absence would prove the character to be a V, while their presence would prove it to be a II.

In written prescriptions the terminal i is usually replaced by j as a further precaution against misinterpretation.

Many physicians omit the f, writing ʒ for fʒ, and ℥ for f℥. Since liquids are measured, and solids weighed, the ʒ and ℥ stand respectively for fʒ and for f℥ in case of liquids, and for the weight units in case of solids.

Roman Numbers.

Numerals.—The Roman numerals are: I = 1; V = 5; X = 10; L = 50; C = 100; D = 500; M = 1000. [ss., from semis, Latin for half, is used in prescriptions.]

Rules for combining the numerals.—

1. Repeating a numeral repeats its value. Thus, III = 3; XX = 20; CCC = 300; etc. But since V, L, and D if doubled would give the equivalent of X, C, and M respectively, these three first-mentioned are never doubled. In place of VV, X is used; in place of LL, C is used; etc.

2. Numerals placed after a numeral of higher value are added to the latter.

Thus, VI = 5 + 1, or 6; XI = 11; XV = 15; XVII = 17; CLXVI = 166.

3. A numeral placed before a numeral of higher value is subtracted from the latter.*

Thus, IV = 5 — 1, or 4; IX = 9; XL = 40; XC = 90; XLVI = 50 — 10 + 5 + 1, or 46; XCVIII = 98.

4. A numeral placed between two higher numerals is always read in connection with the one which follows, and according to Rule 3, is subtracted.

Thus, XIV = 14; XXXIX = 39; LIV = 54; XLIV = 44; MDCCCLXXXIV = 1884; MDCCCVC = 1895.

Problems and Exercises.

36. Write the following expressions of volume as they should be written in a prescription: — (a) 45 minims, (b) 6 fluid drachms, (c) 14 fluid ounces, (d) 3 pints, (e) 1 gallon, (f) 2½ fluid ounces, (g) 2 fluid drachms and 30 minims.

Reduction Descending.

37. Reduce 2 Cong. 1 O. 2 f℥ 1 fʒ 20 ♏ to ♏.

Suggestion.—Reduce the 2 gallons to pints by multiplying by 8; to the product add the 1 pint given; reduce the total number of pints to f℥ by multiplying by 16; add the 2 f℥ given; reduce f℥ to fʒ by multiplying by 8; add the 1 fʒ given; reduce fʒ to ♏ by multiplying by 60; finally add the 20 ♏ given.

38. Reduce $\frac{3}{17}$ Cong. to f℥.

Solution. $\frac{3}{17} \times 8 \times 16 = \frac{384}{17}$ **f℥** $= 22\frac{10}{17}$ **f℥. Since our measures are not graduated in fractions, it is customary to reduce fractions to lower units.—**

$\frac{10}{17}$ f℥ $= \frac{10}{17} \times 8 = \frac{80}{17}$ fʒ $= 4\frac{12}{17}$ fʒ.

$\frac{12}{17}$ fʒ $= \frac{12}{17} \times 60 = \frac{720}{17}$ ♏ $= 42\frac{6}{17}$ ♏.

Then $\frac{3}{17}$ Cong. = 22 f℥ 4 fʒ 42$\frac{6}{17}$ ♏

39. Reduce 3 O. 5 f℥ to ♏. Ans. 25440 ♏. Reduce 6 Cong. to f℥. Ans. 768 f℥.

40. Reduce $3\frac{3}{5}$ f℥ to ♏. Ans. 1728 ♏.

*But only *one* numeral can be so subtracted.

Reduction Ascending.

41. How many fluid ounces in 6000 minims.

Solution.—In one fluid ounce there are 480 minims (See Table B); hence there are as many fluid ounces in 6000 minims as 480 is contained in 6000. Ans. 12½ f℥.

42. A physician wishes to write a prescription for 64 one-fluid-drachm-doses of syrup of hypophosphites. What volume should he prescribe?

43. How should the volume of 8000 ♏ be expressed in order that it might be measured with the customary measures? Ans. 1 pint 5 f℥ 20 ♏.

44. Convert 666 fluid ounces into higher units—pints and gallons.

Solution.—Since there are 16 fluid ounces in a pint, 666 ÷ 16 = number of pints = 41 pints and 10 fluid ounces over. There being 8 pints in a gallon, 41 ÷ 8 = number of gallons = 5 gallons, and 1 pint over. The answer, therefore, is 5 gallons 1 pint 10 fluid ounces.

Remark.—Volumes in apothecaries' measures are expressed by compound denominate numbers rather than by simple denominate numbers with fractions—unless the fraction be ½, in which case it may be used.

Addition.

45. Add the following volumes:—6 gallons; 4 gallons 3 pints 7 fluid ounces 5 fluid drachms; 3 pints 8 fluid ounces 4 fluid drachms.

Suggestion.—Arrange the denominate numbers under each other so that each unit will form a separate column. Add the column of the smallest unit first. If the sum is larger than the equivalent of the next higher unit, reduce to that unit, but enter the remainder under the column added. Proceed in this way until all columns have been added.

Operation.—	gallons	pints	fl. ounces	fl. drachms
	6	—	—	—
	4	3	7	5
	..	3	8	4
	10	7	—	1

46. Add: 15 gallons 5 fl. ounces.
 1 gallon 7 pints 12 fl. ounces.
 5 fl. ounces 6 fl. drachms.
 10 fl. ounces 4 fl. drachms.

Subtraction.

47. Subtract 1 pint 12 fl. ounces from 5 gallons.

Suggestion.—Arrange subtrahend under minuend so that each unit of the former comes under the same unit in the latter; —i. e., gallons under gallons, pints under pints, etc. Subtract from right to left, that is, the lowest unit first, then the next higher, and so on. If then, in any column except the last one to the left, the subtrahend is found to exceed the minuend, one of the next higher unit in the minuend must be reduced.

Operation.—

gallons	pints	fl. ounces.		Gallons	pints	fl. ounces
5				4	7	16
—	1	12	=	—	1	12
4	6	4		4	6	4

48. Subtract $\frac{14}{15}$ f ℥ from $1\frac{3}{4}$ f ℥.

Operation: $15 \times 4 = 60$. Hence 60 is the least common multiple.

$$1\tfrac{3}{4} = \tfrac{7}{4} = \tfrac{105}{60}$$
$$\tfrac{14}{15} = \quad - \tfrac{56}{60}$$
$$\text{Ans.} \quad \tfrac{49}{60} \text{ f ℥}$$

Note.—But this answer would require reduction to lower units in most practical problems. Another process would be to first reduce the subtrahend and minuend to lower units; then to subtract in the usual way.

49. A druggist taps a 36 gallon barrel of alcohol, making an air hole which he forgets to close. By keeping an account of the alcohol drawn off, he finds that the barrel supplied 31 gallons 4 pints 7 fl. ounces. How much was lost by evaporation?

Multiplication.

50. Multiply 5 pints 6 fl. ounces 2 fl. drachms 40 minims by 7.

Suggestion.—Multiply smallest unit first, then the next higher, and so on. In each case reduce the product to the next higher unit when that is possible, and write only the remainder under the unit multiplied.

Operation. —		O	f℥	fʒ	♏
		5	6	2	40
					× 7
Ans.	4 Cong.	5 O.	12 f℥	2 fʒ	40♏

40 ♏ × 7 = 280 ♏ = 4 fʒ and 40 ♏
2 fʒ × 7 = 14 fʒ; 14 fʒ + 4 fʒ = 18 fʒ = 2 f℥ and 2 fʒ
6 f℥ × 7 = 42 f℥; 42 f℥ + 2 f℥ = 44 f℥ = 2 O. and 12 f℥
5 O. × 7 = 35 O.; 35 O. + 2 O. = 37 O. = 4 Cong. and 5 O.

51. Multiply $\frac{2}{7}$ ♏ by 60.
Operation: $\frac{2}{7} \times 60 = \frac{120}{7} = 17\frac{1}{7}$ [♏]

52. Multiply $\frac{3}{7}$ f℥ by $\frac{5}{6}$.
Operation: $\frac{3}{7} \times \frac{5}{6} = \frac{15}{42}$ f℥.

53. Multiply 50 ♏ by $\frac{1}{5}$.
Operation: $50 \times \frac{1}{5} = \frac{50}{1} \times \frac{1}{5} = \frac{50}{5} = 10$ [♏]

Note.—It will be seen that multiplication by a fraction is virtually a method of accomplishing division.

54. Multiply 600 ♏ by 20. Reduce product to higher units. Ans. 1 pint 9 fl. ounces.

55. How much creosote is required to make 4 gross of 5 minim capsules?

Division.

56. Divide 10 gallons 5 pints 4 fl. ounces by 6.

Suggestion.—Divide from left to right, beginning with the highest unit. In case there is an indivisible remainder, reduce this to the next lower unit, and add to the number of that unit before the same is divided.

Operation.—	Cong.	O.	f℥
	6) 10	5	4
	1	6	3 and 2 fʒ 40 ♏

10 Con. ÷ 6 = 1 Cong. and 4 over; 4 Cong. = 32 O.; 32 O. + 5 O. = 37 O. 37 O. ÷ 6 = 6 O. and 1 over; 1 O. = 16 f℥; 16 f℥ + 4 f℥ = 20 f℥. 20 f℥ ÷ 6 = 3 f℥ and 2 f℥ over. 2 f℥ = 16 fʒ ; 16 ʒ ÷ 6 = 2 fʒ and 4 fʒ over. 4 fʒ = 240 ♏; 240 ♏ ÷ 6 = 40 ♏.

57. Divide $\frac{1}{4}$ ♏ by 5.

Operation: $\frac{1}{4} \div \frac{5}{1} = \frac{1}{4} \times \frac{1}{5} = \frac{1}{20}$ [♏]

58. Divide $\frac{1}{4}$ ♏ by $\frac{1}{5}$.

Operation: $\frac{1}{4} \div \frac{1}{5} = \frac{1}{4} \times \frac{5}{1} = \frac{5}{4} = 1\frac{1}{4}$ [♏]

Note.—Just as multiplication by a fraction is a method of effecting division, so a division by a fraction is a method of multiplication.

59. Divide 5 gallons 2 pints 2 fl. ounces by 8.

60. (a.) 3 O. ÷ 24; (b.) 4 Cong. ÷ 15; (c.) 4 f℥ ÷ 7.

61. With 8 fl. ounces 2 fl. drachms of oil of sandalwood in stock, how many 4 minim capsules could be filled? Ans. 990.

62. (a.) How many 2 fl. drachm doses in an 8 fl. ounce mixture? (b.) How many 15 minim doses in 1 pint?

3. Imperial Measure.

This is the fluid measure of Great Britain. It has been in use since 1826, when it superseded the wine measure, which is now the customary fluid measure of the United States.

The Imperial Measure is superior to the measure it displaces inasmuch as it bears a simple relationship to the system of weight official in that country, namely the avoirdupois weight (page 32).

The Imperial gallon, which is the primary unit, is defined as the volume of 10 av. pounds of pure water, at 62°F., and at a barometric pressure of 30 inches.

The Imperial fluid ounce is the volume of 1 av. ounce of pure water, at 62°F., and at a barometric pressure of 30 inches.*

***See foot note page 12.**

Table A.

60 minims ($\mathfrak{m}$) = 1 fluid drachm (fl. drm.)

8 fluid drachms = 1 fluid ounce (fl. oz.)

20 fluid ounces = 1 pint (O.)

8 pints = 1 gallon (C.)

As explained on page 41, the first three Imperial units are smaller, and the pint and gallon larger than the corresponding units of the apothecaries' measure.

Table B.

Gallon.		Pints		Fl. Ounces.		Fl. Drachms.		Minims.
1	=	8	=	160	=	1280	=	76800
		1	=	20	=	160	=	9600
				1	=	8	=	480
						1	=	60

Problems in Imperial Measure.

63. (a.) How many fl. oz. in 5 C.? (b) How many fl. drm. in 5 O.*? (c.) How many $\mathfrak{m}$ in 2 fl. oz.?

64. Reduce 4 C. 3 O. 14 fl. oz. 2 fl. drm. to $\mathfrak{m}$. Ans. 342840 $\mathfrak{m}$.

65. Convert 5000 $\mathfrak{m}$ to higher units—fl. drm., fl. oz., etc.

66. Add 6 C. 4 O. 12 fl. oz.; 7 O. 10 fl. oz.; 3 fl. oz. 40$\mathfrak{m}$.

67. Subtract 5 fl. oz. 4 fl. drm. from 5 C. Ans. 4 C. 7 O. 14 fl. oz. 4 fl. drm.

68. Multiply 2 fl. oz. 4 fl. drm. 40$\mathfrak{m}$ by 24. Ans. 3 O. 2 fl. oz.

69. Divide 3 O. by 48. Ans. 1 fl. oz. 2 fl. drm.

70. Divide 1 C. 2 O. 2 fl. oz. 3 fl. drm. by 16.

71. A Canadian druggist receives a 4 pint bottle of Eaton's syrup from a British drug firm. How many 4 fl. oz. bottles can he fill? Ans. 20.

4. Avoirdupois Weight.

All weighable merchandise, except jewelry and precious stones†, are generally bought and sold in this country by avoirdupois weight,—the metric weight not having been adopted as yet for every-day commercial transactions.††

*O in this paragraph stands for Imperial pint; elsewhere for U. S. pint.
Unless the contrary is expressly indicated, gallons, pints, fl. ounces, fl. drachms, and minims are in this country understood to be those of the U. S. fluid measure.

†Sold by troy weight:—24 grains = 1 pennyweight; 20 pennyweights = 1 ounce; 12 ounces = 1 pound.

††To assist in popularizing the metric system, the firm of E. R. Squibb & Sons has for several years put up their products in packages of metric quantities.

It should be distinctly understood that in the United States all drugs and chemicals which are not bought and sold by metric weight, are bought and sold by avoirdupois weight. *The apothecaries' weight is never used in commercial transactions,* not even in case of the most costly plant principles. An ounce bottle of morphine, or of quinine, contains 437½ grains; an eighth ounce bottle of aconitine contains ⅛ of 437½ grains.

The avoirdupois system of weight was introduced into England about 600 years ago. It is now known in that country as the Imperial weight, and is used in prescription compounding as well as for buying and selling. It is the official weight of the British Pharmacopœia.

In the United States, the units of the avoirdupois weight are officially defined in terms of metric units. The smallest unit, the grain, is defined as equivalent to 64.7989 milligrammes.

Table A.

437½	grains (gr.)	=	1 ounce (oz.)
16	ounces	=	1 pound (lb.)

Table B.

Pound.		Ounces.		Grains.
1	=	16	=	7000
		1	=	437½

Note.—The avoirdupois weight includes a unit called av. drachm, which is $\frac{1}{16}$ of an ounce, and is equivalent to $27\frac{11}{32}$ grains. But this unit is seldom used, it being customary to divide the ounce into halves, quarters, eighths, etc.

Problems in Avoirdupois Weight.

72. (a.) Reduce 16 av. lb. to oz.; (b.) 4 lb. to gr.

73. (a.) How many grains in ⅛ oz. of cocaine? (b.) How many grains in ½ oz. bottle of atropine?

74. How many 3 gr. capsules could be filled from a 1 oz. bottle of quinine?

75. How many grains of cocaine hydrochloride would be left in a ⅛ oz. bottle after removing 30 gr.? Ans. $24\frac{11}{16}$ gr.

76. How many ⅛ gr. morphine sulphate tablet triturates could be made from the contents of a ⅛ oz. bottle?

77. (a.) Reduce 50000 gr. to lb. and oz.; (b) 35000 gr. to lb.; (c.) 3000 gr. to oz.

78. A druggist desires to put up 5 gross of 10 gr. doses of Compound Acetanilid Powder (N. F.) How much of the latter must be made for the purpose? Ans. 1 lb. 200 gr.

79. 15 lb. 6 oz. + 6 lb. 10 oz. 100 gr. + 11 oz. 400 gr. = ? Ans. 22 lb. 12 oz. 62½ gr.

80. From a 5 lb. can of opium the following quantities have been removed:—3 oz., 1¾ oz., 1.64 oz., 175 gr. How much remains?

81. The British Pharmacopœia gives the following formula for Gregory's powder: rhubarb, 2 oz.; light magnesia, 6 oz.; ginger 1 oz. How many 20 gr. doses would this make? Ans. 196 + doses.

5. Apothecaries' Weight.

This is a modification of the old English troy weight (See note page 31 and note page 34) the two being the same except in the units between the ounce and the grain.

The apothecaries' weight has never received legal recognition in this country; but since the apothecaries' grain is identical with the avoirdupois grain, and the latter is now defined in metric units based on the National Prototype Kilogramme, this reference standard may serve also for the apothecaries' system.

The smallest unit—the grain—was originally derived from the average weight of a grain of wheat. Later the weight of a certain volume of water [1 cu. in. of water, in vacuo, and at 62° F. = 252.75965 gr.] was used as the basis

of weight units in England; but the name *grain* for the smallest unit of weight has been retained to this day.*

When the Pharmacopœia of London was compiled (in 1618), the troy (apothecaries') weight was decided upon as the weight to be used in compounding medicines. In England it has since been superseded by the Imperial weight (avoirdupois); but in this country the apothecaries' weight is so firmly established, that the inconveniences incident to the use of one system of weight for compounding, and a different system for buying and selling, will, no doubt, continue to trouble the pharmacist for many years to come.

Table A.

20 grains (gr.)	= 1 scruple	(℈)
3 scruples	= 1 drachm	(ʒ)
8 drachms	= 1 ounce	(℥)
12 ounces	= 1 pound	(℔)

Table B.

℔		℥		ʒ		℈		gr.
1	=	12	=	96	=	288	=	5760
		1	=	8	=	24	=	480
				1	=	3	=	60
						1	=	20

Notes.—(1.) The apoth. pound is seldom used in pharmacy.

(2.) The troy, grain, apoth. grain, and the avoirdupois grain are identical.

(3.) The apoth. ounce, and the troy ounce are the same, but the av. ounce is 42½ gr. smaller.

(4.) The apoth. pound and the troy pound are the same, but the av. pound is 1240 gr. larger.

*In 1266, in the reign of Henry III, the following law was enacted:—"An English silver penny, called a sterling, round and without clipping, shall weigh 32 grains of wheat, well dried and gathered out of the middle of the ear; and twenty pence (pennyweights) do make an ounce, and twelve ounces a pound." Subsequently, in the reign of Henry VII, about 1497, the pennyweight was divided into 24 parts, called grains, in place of into 32; thus creating the system of troy weight as used to this day.

Apothecaries' Weight in Prescriptions.—Roman numerals are used; and the numbers always *follow* the symbols or abbreviations.

In case of fractions, with the exception of ½, expressed by ss , which is the abbreviation for *semis,* Latin for one-half, Arabic numerals are used.

Example:

℞	Acidi arsenosi	gr. $\frac{1}{6}$
	Strychninae sulphatis	gr. $\frac{1}{8}$
	Quininae sulphatis	℈ ij
	Ext. gentianae	ʒ ss
	Ft. pil. no. xx.	

Problems in Apothecaries' Weight.

82. Reduce 4 ℥ 2 ʒ 1 ℈ to gr. Ans. 2060 gr.

83. Reduce 7000 gr. to higher units—℈, ʒ, ℥ and ℔. Ans. 1 ℔. 2 ℥ 4 ʒ 2 ℈.

84. (a.) Reduce 1000 gr. to ʒ; (b.) 7000 gr. to ℔.; (c.) 2000 gr. to ℥; (d.) 437½ gr. to ℥.

85. A certain formula for a horse powder is as follows:

Black antimony	℥ viij
Sulphur	℥ vj
Saltpetre	ʒ vj
Resin	ʒ v
Capsicum	ʒ iij ℈ j

How much will the formula make?

86. Subtract 2 ʒ 1 ℈ 12 gr. from 8 ℥. Ans. 7 ℥ 5 ʒ 1 ℈ 8 gr.

87. The following prescription is to be filled, making eight (8) times the quantity:

℞	Ext. ergotae	ʒ j
	Ferri sulphatis	℈ jss
	Ext. nucis vomicae	gr. viij
	Hydrarg. chlor. corr.	gr. ss
	Make 30 pills.	

How much of each ingredient must be weighed out?

88. Divide 1 ℥ 1 ℈ 10 gr. by 8; (b.) by 80; (c.) by 800; (d.) by .08.

89. Divide 1 ℥ 4 ʒ by $\frac{3}{4}$; (b.) by $\frac{2}{15}$; (c.) by 1.034; (d.) by .0055. Ans. (d.) 272 ℥ 5 ʒ 2 ℈ 9 gr.

90.	℞	Zinci phosphidi	℈ ij
		Ext. nucis vomicae	ʒ j
		Ext. gentianae	ʒ iv
		Make 80 pills.	

How much of each ingredient in each pill?

91.	℞	Camphorae	gr. lxv
		Ammonii carbonatis	gr. xlviij
		Pulv. opii	gr. ix

Mix and divide into 3 gr. doses.
How many will it make?

92.	℞	Rhei	ʒ ij
		Aloes	ʒ iss
		Myrrhae	ʒ j
		Saponis	ʒ j
		Olei menthae piperitae	gr. viij
		Glucosi	ʒ j ℈ j

Mix and divide into 4 gr. pills.

How many should be made? Ans. 104 pills, and 2 gr. over.

93.	℞	Make 48 pills each to contain	
		Atropine	$\frac{1}{75}$
		Morphine	$\frac{1}{8}$

Excipient q. s. to make a 2 gr. pill.

NOTE.—Since $\frac{48}{75}$ gr. of atropine cannot be weighed, proceed as follows:—Weigh out 1 gr. of atropine and mix with 74 gr. of some inert powder, thus making 75 gr. of mixture, of which each gr. represents $\frac{1}{75}$ gr. of atropine. Now weigh out 48 grains of this mixture—the amount containing $\frac{48}{75}$ gr. of atropine.

This rule can also be applied in case of solutions. Sup-

pose $\frac{1}{100}$ gr. of strychnine sulphate is to be contained in each fluid drachm of a 4 fluid ounce preparation. In 4 fl. ounces there are 32 fluid drachms; hence $\frac{32}{100}$ gr. of strychnine sulphate is required—an amount which cannot be weighed. Proceed thus:—weigh out 1 gr. of strychnine sulphate, and dissolve in enough water to make 100 minims. Each minim of this solution contains $\frac{1}{100}$ gr. of strychnine sulphate; therefore 32 minims should be used in the prescription.

Review Questions.

1. Upon what object in nature is the primary unit of the metric system (the meter) based?

2. What serves in England as the "natural standard" for the yard, and thus indirectly for the units of capacity and of weight?

3. How is the yard officially defined in the United States?

4. Is our yard identical in length with the British yard?

5. How many systems of weight are employed in pharmacy in this country?

6. Which two are used in compounding?

7. Which one in commercial transactions only?

8. Which pound is practically obsolete? Which drachm is obsolete?

9. How many gr. in a troy ounce, an apoth. ounce, an Imp. ounce, an avoir. ounce?

CHAPTER II.

Relationship of Systems.

1. METRIC AND ENGLISH LINEAR MEASURES.

Official Equivalents.	Approximate Equivalents.
1 M = 39.37 in*	1 M = 39⅓ in.
1 in. = 25.4001 mm.	**1 in. = 25 mm.**
1 ft. = .304801 M.	1 ft. = .3 M.
1 yd. = .914402 M.	1 yd. = .9 M.

Note.—All equivalents printed in bold faced type should be committed to memory.

While but one connecting link is really necessary, much laborious figuring may be avoided by having several such links—just as in a city many steps may be saved by having more than one bridge across a river. On the other hand, a multiplicity of equivalents is apt to prove confusing to the student and has been carefully avoided in these pages. For a complete table of equivalents see the U. S. Pharmacopœia.

When to employ accurate equivalents, and when approximate equivalents, must be decided in each case that comes up in practical pharmacy; but as a general rule, approximate equivalents are sufficiently accurate.

Problems.

Use Official Equivalents.

1. Reduce 69.325 M. to in.

Solution.—If 1. M. = 39.37 in., then 69.325 M. will equal 69.325 × 39.37 in. = 2729.3 in.

2. Reduce 69.325 in. to M.

Solution.—If 1 M. = 39.37 in., then 69.325 in. will equal as many M. as 39.37 is contained in 69.325.

69.325 ÷ 39.37 = 1.684 [M.] (Ans.)

*According to Capt. A. R. Clark, who made the determination for the British Government, the equivalent is: 1 M = 39.370432 in. But the official equivalent given above is sufficiently accurate for all practical purposes.

3. (a.) Reduce 60½ yd. to M.; (b.) 54¾ ft. to M.

4. Reduce 4 yd. 2 ft. 7½ in. to M.

Suggestion.—Reduce first to in.; then to M.

5. How many inches in 1 dm? in 1 cm? in 1 mm.?

6. (a.) Reduce 154 mm. to in.; (b.) 25 cm. to in.

7. A certain tube has an inside diameter of $\frac{3}{16}$ in. Give this in mm. Ans. 4.76 mm.

8. The tube is 4 ft. 8 in. long. Give in M. Ans. 1.42 M.

Use Approximate Equivalents.

9. Aconite is described in the U. S. P. as being 10 to 20 mm. thick, and from 50 to 75 mm. long. Give its dimensions in inches. Ans. $\frac{3}{8}$ to $\frac{6}{8}$ in. thick and 2 to 3 in. long.

10. Viburnum opulus is from 1 to 1.5 mm. thick, and about 30 cm. long. Give its dimensions in inches.

11. Swedish filtering paper is kept in the laboratory in the following diameters: 5.5 cm., 7 cm., 9 cm., 12.5 cm., 15 cm., 18.5 cm., 24 cm., 38.5 cm. Give these sizes in inches.

12. A druggist receives a prescription for a capsicum plaster 8 cm. by 12 cm. Give size in inches.

Ans. $3\frac{1}{8}$ by $4\frac{6}{8}$ in.

13. A druggist orders a 5 in. funnel (diameter across top); but the jobber sends a 12 cm. funnel. Is the one sent larger or smaller than the one ordered? How much?

2. Metric and Apothecaries' Fluid Measures.

Official Equivalents.		Approximate Equivalents.	
1 c.c. (or mil)	**= 16.23 ♏.**	1 c.c. (mil)	= 16 ♏.†
1 L.	= 33.814 f℥	**1 L.**	**= 33.8 f ℥**
1 f ℥	**= 29.57 mils***	**1 f ℥**	**= 30 mils**
1 O. (pt.)	= 473.179 mils	1 O. (pt.)	= 473 mils
1 Cong.	= 3.78543 L.		

Memorize the equivalents printed in bold faced type.

* More accurately, 29.5737 c.c.

† In the U. S. P. doses this equivalent is further rounded off to 1 c.c. = 15 ♏.

For calculating doses, and for all pharmaceutical work not requiring very great accuracy, the approximate equivalents may be used. In the U. S. P. 1 c.c. = 15 ♏ is considered sufficiently accurate for dose calculations.

Problems.

Use Official Equivalents.

14. Reduce 3 pints to c.c.

Solution.—3 pints = 48 f℥; 48 × 29.57 = 1419.36. Hence 3 pints = 1419.36 c.c.

15. Reduce 1 Cong. 2 O. 6 f℥ to c.c.

Suggestion.—Reduce to f ℥; then to c.c.

16. Reduce 93.29 c.c. to ♏. Ans. 1514 ♏.

17. Reduce $9\frac{7}{19}$ c.c. to ♏. Ans. 152 ♏.

18. Reduce (a.) 300 ml. to f ℥; (b.) 3.78543 L. to pints.

19. Reduce 4.5 ml. to ♏. Ans. 73.035 ♏.

20. Reduce (a.) 40¾ ♏ to c.c.; (b.) 10 f ℥ to c.c.

21. How many f ℥ will a 500 c.c. flask hold?

22. How many c.c. will a pint bottle hold? Ans. 473.179 c.c.

Use Approximate Equivalents.

23. Express the following doses in metric measure: (a.) croton oil, 1 to 2 ♏; (b.) tr. belladonna, 5 to 15 ♏. (c.) infusion buchu, 1 to 2 f℥; (d.) tr. cinchona, 1 f ʒ.

24. Express the following formula in apoth. measure:

			Ans.
Castor oil	75	mils	2 f ℥ 4 f ʒ
Mucilage of acacia	37.5	"	1 f ℥ 2 f ʒ
Orange flower water	25	"	6 f ʒ 40 ♏
Cinnamon water	62.5	"	2 f ℥ 40 ♏

25. Express in metric measure the following formula for a cough medicine:

Tr. opium	f℥ vj
Fl. ext. ipecac	f℥ j
Fl. ext. sanguinaria	f℥ j
Syr. squill	f℥ iij
Syr. wild cherry	f℥ ix
Syr. tar q. s. ad	O. j

26. Express the following doses in apothecaries' measure:—sol. potass. arsenite, 0.3 c.c.; sol. potass. citrate, 15 c.c.; fl. ext. ipecac, 0.9 to 1.9 c.c.; spt. glonoin, 0.06 to 0.12 c.c.; tr. gelsemium, 0.6 to 1.25 c.c.; comp. decoction of sarsaparilla, 120 to 180 c.c.; inf. cinchona, 30 c.c.; oil of eucalyptus, 0.6 to 0.9 c.c.; syr. of tar, 3.7 to 7.5 c.c.

27. A druggist receives four "metric prescriptions"; the first for a 60 c.c. solution, the second for a 120 c.c. liniment, the third for a 360 c.c. emulsion, the fourth for a 15 c.c. eye wash. State in fluid ounces the size of the bottle to be selected in each case.

Note.—American-made prescription bottles are commonly gauged in fluid ounces.

3. Apothecaries' and Imperial Measures.

The Imperial measure differs from our apothecaries' measure in two respects:—the Imperial minim equals but 0.96014 ♏ (U. S.); and the Imperial pint is divided into 20 Imperial ounces, while the pint (U. S.) contains only 16 f℥ (U. S.)

The equivalents usually employed are:

1 Imperial minim (♏) = .96 ♏ (U. S.)

1 Imperial fluid drachm (fl. dr.) = .96 fℨ (U. S.)

1 Imperial fluid ounce (fl. oz.) = .96 f℥ (U. S.)

1 Imperial pint (O.) = 1.2 O. (U. S.) [accurately, 1.20017501].

I Imperial gallon (C.) = 1.2 Cong. (U. S.) [accurately, 1.20017501].

28. Convert 6 fl. oz. Imp., into f℥, U. S.

Solution.—1 fl. oz. = .96 f℥. And 6 × .96 = 5.76.

Therefore 6 fl. oz. = 5.76 f℥.

But since our customary measures are not graduated in decimal fractions of each unit, convenience in measuring requires that such decimal fractions be reduced, so as to express the amount in integers of a lower unit (denomination). Hence .76 f℥ should be reduced to fʒ: and should there be a fractional fʒ in the product, this fractional fluid drachm should be reduced to minims, as follows:

$.76 \times 8 = 6.08$. Hence .76 f℥, = 6 f ʒ and .08 fʒ; and since $.08 \times 60 = 4.80$, .08 fʒ = 4.8 ♏.

Then 5.76 f℥ = 5 f℥ 6 fʒ 4.8 ♏.

29. Convert 6 f℥ into Imp. measure. Ans 6 fl. oz. 2 fl. drm.

30. Convert 1 Imperial pint into pints, f℥, fʒ and ♏ of U. S. measure. Ans. 1 O. 3 f℥ 1 fʒ 36 ♏. (U. S.)

31. Convert 3 Imperial pints into Apothecaries' measure.

32. Convert 3 pints U. S. into Imperial measure.

33. Convert 6 pints 6 fluid ounces 6 fluid drachms Imp., into U. S. apothecaries' measure.

Suggestion.—Reduce to fluid drachms before converting into U. S. measure. And should the final answer contain a fraction of a drachm, reduce this to minims.

34. Convert the Imperial measures in the following Canadian prescription into U. S. apoth. measure:

Liq. ext. bellad.	10 fl. oz.
Camphor	1 oz.
Dist. water	2 fl. oz
Alcohol q. s. ad	20 fl. oz.

Note.—If the ingredients were all liquids, it would be allowable to read f℥ in place of fl. oz. A somewhat larger volume of liniment would be dispensed in that case, but the relative proportions of the ingredients would not be changed. In the presence of solids, however, it is different; for the relationship between the Imperial ounce and the Imperial fluid ounce on the one hand, and the apoth. ounce and the apoth. fluid ounce on the other, is not the same. See page 30 and page 62. However, the difference is so small that it is usually ignored.

4. Metric and Imperial Measures.

The following equivalents may be used:

1 Imp. fl. oz. = 28.39 mils or c.c.
1 c.c. = 16.9 ♏ (Imp.)

But the equivalents are seldom required and need not be memorized. Should it be necessary to convert metric measure into Imperial, or vice versa, and the equivalents are not at hand, convert the measure given to apothecaries' and this to the measure required, as indicated under problems No. 35 and No. 36.

35. Convert 8 fl. oz. (Imp.) into c. c.

Solution.— $8 \times .96 = 7.68$. ∴ 8 fl. oz. = 7.68 f℥. $7.68 \times 29.57 = 227$. ∴ 7.68 f℥ = 227. c. c.

36. Convert 500 c. c. into fl. oz.

Process.— $500 \div 29.57$ = number of f℥.

Number of f℥ $\div .96$ = number of fl. oz.

37. Convert 40 ♏ (Imp.) into c. c. Ans. 2. 3 c. c.

38. Convert 1 L. into Imperial measure—pints, fluid ounces, etc. Ans. 1 pint 15 fl. oz. 1 fl. drm. 45 ♏.

39. Convert 50 gallons (Imp.) into Liters.

Note.—The sign ∴ stands for then, hence or therefore.

Approximate Measures.

The following domestic measures are in common use:

1 Tumblerful = 8 f ℥ = nearly 240 c.c.
1 Teacupful = 4 f ℥ = nearly 120 c.c.
1 Wineglassful = 2 f ℥ = nearly 60 c.c.
1 Tablespoonful = ½ to ⅔ f ℥ = 15 to 20 c.c.
1 Dessertspoonful = ¼ to ⅓ f ℥ = 7.5 to 10 c.c.
1 Teaspoonful = ⅛ to ⅙ f ℥ = 3.75 to 5 c.c.
1 Drop (watery liquids) = 1 ♏ = about 0.06 c.c.
1 Drop (alcoholic liquids) = ½ ♏ = about 0.03 c.c.

But the U. S. P. IX gives the following as sufficiently accurate: 1 tablespoonful = ½ fl. ounce or 15 mils; 1 dessertspoonful = 2 fluidrachms or 8 mils; 1 teaspoonful = 1 fluidrachm or 4 mils.

The first equivalent given in the table is the old, and the second, the new, and in conformity with the actual capacity of spoons. In case of very active medicines this discrepancy between the equivalents commonly used and the actual capacity of spoons used by the patient, should not be

overlooked. If it is intended that a 1 f ʒ dose be administered, the directions should read "¾ teaspoonful, etc."

Another source of error in dosage is the use of a dessert spoon in place of a tablespoon.

It should be remembered also that the drop is not a definite volume, and that it seldom measures exactly 1 ♏, even in case of pure water. The size of the drop is dependent not only on the nature of thel iquid, but is influenced by the temperature, and by the size and shape of the mouth of the vessel from which the drop is emitted. In case of medicine droppers, which are much used in prescription work, the drop varies directly with the *outside* diameter of the lower extremity of the tube.

Problems.

40. Write a prescription for 32 teaspoonful doses, each to contain 1½ ♏ of tincture of aconite, and enough compound elixir of taraxacum to make the proper volume.

41.	℞	Antim. et potass. tart.	gr. iv
		Liq. amm. acet.	f℥ iv
		Spt. aeth. nit.	f℥ ij
		Tr. aconiti	fʒ j
		Syr. q. s. ad	f℥ viij

Teaspoonful 3 times a day.

Calculate the single dose for the first four ingredients.

42.	℞	Tincturae veratri viridis	3	5
		Spiritus aetheris nitrosi	30	
		Liquoris potassii citratis	20	
		Syrupi zingiberis q. s. ad	240	

Calculate the amount of each of the first three ingredients in a tablespoonful dose.

43. Write a metric prescription for 8 wineglassful doses, each to contain 0.5 c.c. of tincture nux vomica, and enough compound infusion of gentian (Br.) to make the proper volume.

44.	℞	Ac. hydrocyan. dil.	f℥ ij
		Aq. amygd. amar. q. s. ad	f℥ iv
		Teaspoonful.	

(a.) How much dilute hydrocyanic acid in each fʒ dose?

(b.) How much of the acid would be administered for a dose if a common teaspoon were used?

METRIC AND APOTHECARIES' WEIGHTS.

Official Equivalents.	Approximate Equivalents.
1 gr. = 64.8* mg.	**1 gr. = 65 mg., or .065 Gm.**
1 ℥ = 31.1035 Gm.	**1 ℥ = 31 Gm.**
1 Gm. = 15.4324 gr.	**1 Gm. = 15.4 gr.**

In reducing gr. to Gm., use the equivalent, 1 gr. = .065 Gm., rather than the equivalent, 1 Gm. = 15.4 gr. For multiplication involves less work than does the process of division.

In computing doses, the equivalent, 1 gr. = 65 mg., is sufficiently accurate, and is generally used.

Problems.

Use Official Equivalents.

Convert 6 ℥ 2 ʒ 1 ℈ 12 gr. into Gm. Ans. 196.47 Gm.

45. (a.) Convert $\frac{3}{16}$ gr. into mg.; (b.) 6.4 gr. into mg. Ans. (a.) 12.1 mg.; (b.) 414.7 mg.

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*The official table gives 64.79; but as the accurate equivalent is 64.7989, 64.8 is more nearly correct than 64.79.

†Accurately, 15.43235639 gr.

46. (a.) Convert 6.4 mg. into gr.; (b.) 6.042 Gm. into gr.

47. Convert 200 Gm. into apothecaries' units. Ans. 6 ℥ 3 ʒ 1 ℈ 6½ gr.

Use Approximate Equivalents.

48. Give the following doses in metric weight: Arsenous acid. $\frac{1}{30}$ to $\frac{1}{15}$ gr.; atropine, $\frac{1}{100}$ to $\frac{1}{60}$ gr.; ext. belladonna leaves, $\frac{1}{8}$ to ½ gr.; ext. rhubarb, 1 to 10 gr.; ferric citrate 3 to 20 gr.; salol, 5 to 30 gr.; sodium salicylate, 5 to 60 gr.; cascara sagrada, 15 to 60 gr.; coca, ¼ to 2 ʒ; Rochelle salt, 1 to 8 ʒ.

					Ans.
49.	℞	Bismuthi subcarb.	ʒ iij	=	11.7 Gm.
		Morphinæ sulph.	gr. j	=	0.065 Gm.
		Pulv. aromat.	ʒ j	=	3.9 Gm.
		Make 12 powders.			

(a.) Convert to metric weight. (b.) How many mg. of morphine sulphate in each dose?

50. Express the following doses in apothecaries' weight: Aconitine, .0001 Gm.; hyoscyamine sulphate, .0008 Gm.; ipecac (as emetic), 1.4 Gm., jalap, .65 to 1.3 Gm.; ext. nux vomica, .008 to .016 Gm.; antimonial powders, .2 to .52 Gm.; quinine sulphate, .065 to 1.5 Gm.; effervescent magnesium sulphate, 7.77 to 31.1 Gm.

51. Express the quantities in the following prescription in apothecaries' weight:

				Ans.
℞	Quininæ sulphatis	3	25	= 2 ℈ 10 gr.
	Strychninæ sulphatis		065	= 1 gr.
	Ferri phosphatis	6	50	= 1 ʒ 2 ℈
	Make 50 pills.			

7. Metric and Avoirdupois Weights.

Official Equivalents.	Approximate Equivalents.
1 gr. = 64.8* mg.	**1 gr. = 65 mg.**
1 oz. = 28.35 Gm.	1 oz. = 28⅓ Gm.
1 lb. = 453.592 Gm.†	**1 lb. = 454 Gm.**
1 Gm. = 15.4324 gr.	**1 Gm. = 15.4 gr.**
1 Kg. = 2.2 lb.‡	**1 Kg. = 2.2 lb.**

The metric pound is 500 Gm., or ½ Kg.

Problems.

Use Official Equivalents.

52. Convert (a.) 5 oz. into Gm.; (b.) 3 lb. into Gm.; (c.) 5 lb. into Kg.; (d.) 5 lb. 5 oz. 200 gr. into Gm. Ans. (d.) 2422.66 Gm.

53. Convert (a.) 60 Gm. into gr.; (b.) 600 Gm. into oz.; (c.) 6 metric pounds into av. pounds; (d.) 5675.45 Gm. to avoir. weight. Ans. (d.) 12 lb. 8 oz. 85.6 gr.

Use Approximate Equivalents.

54. Express the quantities in the following formula for menthol plaster in metric weight:

Menthol	2 oz.
Yellow Wax	2 oz.
Resin	1 oz.
Lead Plaster	15 oz.

55. (a.) Convert 5 lb. into Gm.; (b.) 5 oz. into Gm.; (c.) 5 gr. into mg.; (d.) 50 Gm. into gr.

56. Convert the quantities in the formula for compound cathartic pills into avoirdupois weight:

Com. ext. colocynth	800 Gm.
Mild mercurous chloride	600 Gm.
Resin jalap	200 Gm.
Gamboge	150 Gm.

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*Accurate equivalent is 64.7989 mg.
†Accurately, 453.592653 Gm.
‡Accurately, 2.20462 lb.

57. A druggist buys the following list of goods:

5 Kg.	Powd. acacia.
½ Kg.	Iodoform.
2 Kg.	Ether.
100 Gm.	Lithium citrate.
25 Gm.	Amyl acetate.
500 mg.	Aconitine.

(a.) Convert these weights into avoirdupois units.

(b.) Box and packing being figured at 8 Kg., how much would the gross weight be in avoir. units? Ans. 34 lb. 2 oz.

Avoirdupois (or Imperial) and Apothecaries' Weights.

Equivalent:

1 gr. apoth. = 1 gr. av. or Imp.

Note.—Since the grain apoth. is identical with the grain avoir., any weight in one of these systems can be converted into weight in the other, by reducing to grains, and then to the higher units of that other system.

Thus, 6 ℥ = 2880 gr. = 6 oz. 255 gr.
6 oz. = 2625 gr. = 5℥ 3 ʒ 2 ℈ 5 gr.

To use the equivalent, 1 ℥ = 1.1 oz.* would be practically no shorter (since the fraction would have to be reduced to smaller units), and the answer would be only approximately correct.

Problems.

58. (a.) Convert 2 ℥ into avoir. weight.
(b.) Convert 14¼ ℥ into avoir. weight.

59. (a.) Convert 15 ℥ 3 ʒ 2 ℈ 10 gr. into avoir. weight.
(b.) Convert 3℥ 3ʒ 2℈ 15 gr. into Imp. weight.

		Ans.
60. ℞	Ext. Stramonii	ʒij = 120 gr.
	Adipis Benz.	℥ij = 2 oz. 85 gr.

Express quantities in avoir. weight.

*1℥ = 1.1 oz. av or Imp. (accurately, 1.097143).

Note.—Ointments, dusting powders, etc., are usually prescribed in quantities of 1 ℥ or more. But the 2 ʒ weight is the largest in the common set of prescription weights, and in many stores larger apoth. weights are not at hand. The proper procedure then is to reduce the apoth. weight to avoir. weight, in order that the counter weights, which are avoir., may be utilized. For instance, 2 ℥ of petrolatum is to be weighed. 2 ℥ = 2 oz. and 85 gr. So the 2 oz. weight of the counter set is used, together with a 1 ʒ weight, a 1 ℈ weight, and a 5 gr. weight of the prescription set. To weigh out 1 oz. when 1 ℥ is prescribed, involves a change in proportion of active medicine to base or diluent—a change which the pharmacist is not justified in making, except with the consent of the physician.

61.	℞	Sodium sulphate	℥ iij
		Sodium chloride	℥ viij
		Linseed, powd.	℥ viij

Suppose av. oz. were weighed in place of the apoth. ounces. How much difference would it make in the weight of the mixture?

Note.—In this prescripion the ℥ is the only unit used. And should avoir. ounces be dispensed in place of apoth. ounces, the proportions would not thereby be changed. There would still be 3 parts of sodium sulphate to 8 parts of the other ingredients. So there could be no serious objection to such a change.

62. (a.) Convert 3 oz. av. into apoth. weight.
Ans. 2℥ 5 ʒ 2℈ 12½ gr.

(b.) Convert 5 oz. Imp. into apoth. weight.
Ans. 4 ℥ 4 ʒ 1 ℈ 7½ gr.

(c.) Convert 3 oz. 300 gr. into apoth. weight.

(d.) Convert 7 $\frac{1}{16}$ oz. into apoth. weight.

63. A pharmacist dispenses ʒ iv of aristol from a 1 oz. package. How many grains remain? How many ʒ?

64. How many 1℈. doses of bismuth sub-nitrate could be dispensed from a 4 oz. package of the salt?

CHAPTER III.

VOLUMES AND WEIGHTS.

A. Specific Gravity (Relative Density, Specific Weight.)

By weighing equal volumes of various substances the fact is made apparent that hardly two substances can be found which weigh exactly alike volume for volume. Glycerin weighs one and one-fourth as much, volume for volume, as water. Ether is not quite three-fourths as heavy as water. Mercury is nearly twenty-three times as heavy as lithium, but not quite twice as heavy as iron. Thus the relation between weight and volume—in other words, the density,—differs with nearly every substance, but is always (under like conditions) the same for the same substance. This being true, density serves as a characteristic, by which substances may be identified, or their purity be determined.

The most convenient way of expressing the density of a substance is by comparison with the density of another substance. The standard selected for such comparisons, for solids and liquids, is pure water*, the density of which is taken as unity—as 1.000. The density of any substance twice as heavy as water may then be expressed by 2.000: the density of a substance one-half as heavy as water, by .5; —these numbers indicating not weights, but ratios between weights.

When density is thus expressed (by comparison), it is properly called *relative density;* but its synonym, *specific gravity,* is more generally used, and will be used in the succeeding pages.

To repeat: *Density* is the relation which the weight of a body bears to its volume. *Specific gravity* is the density of a body as compared with the density of water, or with some other arbitrarily established standard.

Since the volume, and hence the density, of a body varies with the temperature, it is necessary to have a stand-

*For gases, hydrogen at 0°C is taken as the standard of density.

ard temperature for specific gravity determinations. The temperature adopted by the U. S. Pharmacopoeia is 25° C., both for the standard—water—and for the substance of which the specific gravity is to be determined. This is expressed by

$$\frac{25^\circ\ \mathrm{C.}}{25^\circ\ \mathrm{C.}}$$

In Europe it is customary to make the determination at [or near] 15° C., but to compare with water at 4° C., the temperature at which water reaches its greatest density. These temperatures are expressed by

$$\frac{15^\circ\ \mathrm{C.}}{4^\circ\ \mathrm{C.}}$$

Calculating Specific Gravity.

To find the specific gravity of a body divide its weight by the weight of an equal bulk of water. Fractions in the quotient are stated as decimals; and in case these are interminate, they are usually carried to the third place.

The method employed in the determination of the *equal bulk of water,* varies with the nature of the substance under examination. In case of liquids, a small bottle is completely filled with water at the proper temperature, and weighed. Then the same bottle is filled with the liquid, and weighed. In each case the weight of the bottle itself is subtracted, giving in the latter case the net weight of the liquid, and in the first case the net weight of an *equal bulk of water.**

Problem.—A bottle holds 96.54 Gm. of water, and 94.78 Gm. of a certain oil. What is the sp. gr. of the oil?

Operation: 94.78 ÷ 96.51 = .981
(wt. of body of oil) ÷ (wt. equal bulk of water) = sp. gr.

The specific gravity of a solid, in mass, is found as follows: The body is weighed in air, in the usual manner. Then it is weighed in water being suspended in the latter from a balance arm by means of a hair. In water the body

*Another method is to make use of floats or buoys which indicate the sp. gr. of the liquid by the depth to which they sink. Such instruments are called hydrometers. The graduated scale on a modern hydrometer indicates the sp. gr. directly; but the older instruments carry arbitrary scales, some of which, notably those of Beaume, are still in use. For relation of degrees Beaume to sp. gr. see chapter XI.

is found to weigh less than in air. The difference between the two weights (the loss) is due to the buoyant force of the water, and this is exactly equal to the weight of just as much water as the body displaces. In other words, *the loss is exactly equal to the weight of an equal bulk of water.*

Problem.—A piece of ore weighs 5.4 Gm. in air. Suspended in water, from the arm of a balance, it weighs 4.01 Gm. Calculate the sp. gr. of the ore.

Operation.—Wt. in air = 5.4 Gm. Wt. in water = 4.01 Gm.

Loss in water = 1.39 Gm. (wt. of equal bulk of water). Then 5.4 Gm. ÷ 1.39 [Gm.] = 3.884 (sp. gr.)

If the solid is found to be lighter than water, a sinker must be used to make complete immersion possible, thus making the calculation more complicated.* If the solid is soluble in water, another liquid in which the solid is insoluble must be selected, and this taken cognizance of in the calculation.†

Problems.

1. A certain bottle holds 500 Gm. of water. Of a certain solution it holds 650 Gm. Calculate the sp. gr. of the solution. Ans. 1.3.

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*Problem.—A piece of paraffin weighs 2.895 Gm. Attached to sinker the total weight is 14.086 Gm. The sinker and paraffin in water weigh 8.258 Gm., while the sinker by itself in water weighs 8.652 Gm. Calculate sp. gr. of the paraffin.

Operation.—	Wt. of sinker in air	11.191 Gm.
	Wt. of sinker in water	8.652 Gm.
	Wt. of water displaced by sinker	2.539 Gm.
	Wt. of paraffin plus sinker in air	14.086 Gm.
	Wt. of paraffin plus sinker in water	8.258 Gm.
	Wt. of water displaced by paraffin plus sinker	5.828 Gm.
	Wt. of water displaced by sinker	2.539 Gm.
	Wt. of water displaced by paraffin	3.289 Gm.

Then 2.895 (wt. of paraffin in air) ÷ 3.289 (wt. of equal bulk of water) = .880 (sp. gr. of paraffin.)

†*Problem.*—A crystal of alum weighs 3.824 Gm. in air, and 1.901 Gm., suspended in oil of turpentine, having a sp. gr. of .860. What is the sp. gr. of the alum?

Operation.—	Wt. of alum in air	3.824 Gm.
	Wt. of alum in oil turpentine.	— 1.901 Gm.
	Wt. of oil turp. displaced.	1.923 Gm.

Then 3.824 Gm. ÷ 1.923 [Gm.] = 1.988 (sp. gr. of alum, if oil turpentine were standard of density).

Finally, 1.988 × .860 (sp. gr. of oil turp.) = 1.709 (sp. gr. of alum, referred to water, the standard of density).

2. A certain piece of metal weighs 10.10 Gm. in air, and 8.65 Gm. suspended in water. What is the sp. gr. of the metal? Ans. 6.965.

3. A certain iron cylinder holds 50 lb. of mercury. Of water it holds 3.69 lb. What is the sp. gr. of mercury?

4. What is the sp. gr. of a crystal which weighs 2.34 Gm. in air, and 1.18 Gm. suspended in water?

5. A certain bottle holds 245 gr. of water. Of oil of peppermint it holds 220.5 gr. What is the sp. gr. of the oil?

6. A certain bottle holds 3 oz. (av.) of water. Of nitric acid the same bottle holds 120.2607 Gm. What is the sp. gr. of the nitric acid. Ans. 1.4.

Note.—When a denominate number is to be divided by another denominate number, both must be in the same unit (denomination.)

7. An av. oz. of a volatile oil measures 35 c.c. What is the sp. gr. of the oil?

Solution.— 1 av. oz. = 28.35 Gm.; and 35 c.c. of water weigh 35 Gm.
Hence— 28.35 Gm. ÷ 35 = .81 (sp. gr.).

8. The weight of 5 c.c. of a certain liquid is 100 gr. What is the sp. gr? Ans. 1.296.

9. If a minim of water weighs .95 gr., and an av. oz. of an oil measures 500 ♏, what is the sp. gr. of the oil?

Solution.—500 ♏ of water weigh 500 × .95 = 475 gr.
500 ♏ of oil weigh 1 oz. = 437.5 gr.
Then 437.5 gr. ÷ 475 gr. = .921 (sp. gr.)

10. What is the sp. gr. of a liquid 1 lb. of which measures ½ L?

TABLE OF SPECIFIC GRAVITIES.

The approximate specific gravity of the more common liquids should be memorized.

Water	1.00
Alcohol	0.81
Glycerin	1.25
Chloroform	1.5
Ether	0.7
Ammonia Water	0.96
Sulphuric Acid	1.83
Hydrochloric Acid	1.16
Nitric Acid	1.4
Syrup	1.3
Mercury	13.5
Etc.	

Specific Volume.

Specific volume expresses the same fact expressed by specific gravity; namely, the density of a body as compared with the density of water.

To find the specific gravity, the weight of a body is compared with the weight of an equal volume of water. To find the specific volume, the volume of a body is compared with the volume of an equal weight of water. Specific volume is, therefore, the reciprocal of specific gravity. The greater the specific gravity of a body, the smaller is its specific volume; and vice versa.

Calculating Specific Volume.—Divide the volume of the body by the volume of an equal weight of water.

$$\text{Sp.V.} = \frac{\text{vol. of body}}{\text{vol. of equal wt. of water.}}$$

Fractions in the quotient are expressed in decimals, and are carried to the third place, as a rule.

11. A certain weight of oil measures 60 c.c. The same weight of water measures 52 c.c. What is the specific volume of the oil?

$$\begin{array}{ccccc} 60 \text{ c.c.} & \div & 52 \text{ c.c.} & = 1.153 \\ \text{Vol. of oil.} & \div & \text{Vol. of equal wt. of water} & = \text{Sp. V.} \end{array}$$

12. A certain weight of a certain acid measures 80 c.c. The same weight of water measures 4 f ℥. What is the sp. v. of the acid? Ans. .676.

Calculating Specific Volume from Specific Gravity.
Rule.—Divide the sp. gr. into 1.000. The quotient is the sp. v.

$$\text{Sp. V.} = \frac{1.000}{\text{Sp. Gr.}}$$

13. Glycerin has a sp. gr. of 1.25. What is its sp. v.?

$$1.00 \div 1.25 \text{ (sp. gr.)} = .800 \text{ (sp. v.)}$$

14. Sulphuric acid has a sp. gr. of 1.8. What is its sp. v.?

15. Ether has a sp. gr. of .716. What is its sp. v.? Ans. 1.396.

Calculating the Specific Gravity from the Specific Volume. Rule.—Divide the sp. v. into 1.000. The quotient is the sp. gr.

$$\text{Sp. Gr.} = \frac{1.000}{\text{Sp. v.}}$$

16. Chloroform has a sp. v. of .677. What is the sp. gr? $1.00 \div .677$ (sp. v.) $= 1.476$ (sp. gr.)

B. Reducing Volume to Weight.

1. Mils or Cubic Centimeters to Grammes.

The weight of 1 c.c. of water is 1 Gm. The specific gravity of water is 1.000, it being the standard of density. One c.c. of any liquid having a specific gravity of 1.000, will, therefore, weigh 1 Gm. One c.c. of a liquid having a sp. gr. of 2.000, will weigh 2 Gm.; and one c.c. of a liquid having a sp. gr. of .75, will weigh .75 Gm. In short, *the specific gravity of a liquid indicates the weight in Grammes of one cubic centimeter of it.* Then any volume expressed in cubic centimeters may be converted into weight expressed in Grammes by multiplying the number of cubic centimeters by the specific gravity:—

No. of c.c. × sp. .gr. = No. of Gm.

Problems.

17. What is the weight in Gm. of 500 c.c. of glycerin, having a sp. gr. of 1.25?

$$\begin{array}{ccccc} 500 & \times & 1.25 & = & 625. \\ \text{(No. of c.c.)} & \times & \text{(sp. gr.)} & = & \text{(No. of Gm.)} \end{array}$$

18. 2 L. of sulphuric acid, sp. gr., 1.826, weigh how many Gm.? Ans. 3652 Gm.

19. What is the weight in Gm. of 650 c.c. of alcohol, sp. gr., .82? Ans. 533 Gm.

20. Ether has a sp. gr. of .716. How many Gm. will 5.67 c.c. weigh? Ans. 4.0597 Gm.

21. Calculate the weight in Gm. of 25 L. of syrup, sp. gr., 1.3. Ans. 32500 Gm.

2. Fluid Ounces to Grains.

The weight of one fl. ounce of water, at 25° C., is 454.6 gr. Water being the standard of density, it follows that any liquid having a sp. gr. of 1.000, will weigh 454.6 gr. per fl. ounce; that a liquid with a sp. gr. of 2.000, will weigh twice 454.6 gr. per fl. ounce; and that a liquid with a sp. gr. of .900, will weigh .9 of 454.6 gr. per fl. ounce. In every case 454.6 multiplied by the sp. gr. of the liquid will give the weight in grains of one fl. ounce. Then any volume in fl. ounces may be reduced to grains by the following rule:

454.6 gr. × sp. gr. × no. of f ℥ = wt. in gr.

22. Calculate the weight in gr. of 2 pints 3 fl. ounces of nitric acid, sp. gr., 1.4.

Solution.—454.6 gr. × 1.4 = 636.44 gr. (wt. in gr. of 1 fl. ounce.)

2 pints 3 fl. ounces = 35 fl. ounces.

Then, 636.44 gr. × 35 = 22275 gr. Ans.

Usually the weight in gr. is subsequently to be reduced to weight in higher units.

Note—When decimals in a product are dropped, this should be done with the least error:—1.158 for instance, should be given as 1.16, not as 1.15.

23. (a.) Find weight in gr. of 14 f ℥ of mercury, sp. gr., 13.5. (b.) Express in higher units, avoirdupois.

24. (a.) Calculate weight in av. lb. of 36 gallons of alcohol, sp. gr., .81. (b.) Calculate weight in av. lb. of 1 pint of syrup, sp. gr., 1.31.

25. Calculate weight. in av. lb. of 1 pint of water. Ans. 1 lb. 273.6 gr.

26. Calculate weight in av. lb. of 1 pint of benzine, sp. gr., .67. Ans. .696 lb.

27. Calculate weight in av. lb. of 1 pint of sulphuric acid, sp. gr., 1.83. Ans. 1.9 lb.

[Is it a fact that "a pint is a pound"?]

28. Calculate weight, in units of the apoth. system, of 1 O. 3 f ℥ 2 f ʒ 40 ♏ of alcohol, sp. gr., .81.

29. Calculate weight in Gm. of 1 gallon of ammonia water, sp. gr., .96. Ans. 3632.6 Gm.

30. Calculate weight in av. lb. of 8 L. of stronger ammonia water, sp. gr., .9.

3. Minims to Grains.

Since 1 fl. ounce equals 480 minims, and since 1 fl. ounce of water weighs 454.6 grains, each minim of water weighs $\frac{454.6}{480}$ grains.

But $\frac{454.6}{480}$ is too cumbersome a fraction for speedy work; a decimal fraction would be more convenient.

$$\frac{454.6}{480} = .947.$$

And this fraction may, for most practical purposes, be rounded off to .95.

Then, if .95 gr. is taken as the weight of 1 ♏ of water, the weight of 1 ♏ of any liquid must be .95 gr. × sp. gr.; and the rule for reducing ♏ to gr. must be—

.95 gr. × sp. gr. × no. of ♏ = weight in gr.

Problems.

31. Find weight in grains of 160 ♏ of solution of ferric chloride, sp. gr., 1.3.

Solution.—

.95 gr.	×	1.3	=	1.235 gr.
Wt. of 1 ♏ of water	×	sp. gr.	=	wt. of 1♏ of solution.

Then, 1.235 gr. × 160 = 197.6 gr. (Ans.)

32. Find weight in gr. of 75 ♏ of sulphuric acid, sp. gr., 1.8. Ans. 128.25 gr.

33. Find weight in gr. of 200 ♏ of alcohol, sp. gr., .81.

34. Find weight in gr. of 120 ♏ of chloroform, sp. gr., 1.48. Ans. 168.7 gr.

4. Other Units Apoth. Measure to Apoth. Weight.

One of the chief advantages of the apothecaries' systems lies in this, that the three units of volume most commonly used in prescription work, and the three most commonly used weight units, are parallels. Thus, the smallest unit of volume, the minim, has its parallel in the grain, which, as has been seen, is, however, not exactly equivalent to a minim; and just as 60 minims make 1 fl. drachm, so 60 grains make 1 drachm; and as 8 fl. drachms make 1 fl. ounce, so 8 drachms make 1 ounce. It follows, then, that if 1 minim of water weighs .95 grains, 1 fl. drachm of water must weigh .95 drachms (ʒ), and 1 fl. ounce, .95 ounces (℥). Hence the following rule to reduce fl. drachms of a liquid to weight in drachms:

.95 ʒ* × sp. gr. × No. of f ʒ = weight in ʒ.

And the following rule to reduce fl. ounces to ounces:

.95 ℥* × sp. gr. ×No. of f ℥ = weight in. ℥.

Note.—If the student cannot harmonize this rule with the one given on page 57, he should carefully review pages 55, 56 and 57.

Problems.

35. What would be the weight in ℥ of 1 O. 6 f℥ of stronger ammonia water, having a sp. gr. of .9? Ans. 18.8 ℥

36. What would be the weight in ʒ of 3½ f ʒ of lactic acid, having a sp. gr. of 1.2? Ans. Nearly 4 ʒ.

---

*Exactly, .947 gr., as explained on page 57.

37. What would be the weight in ℨ of 7¾ f ℨ of phosphoric acid, sp. gr., 1.71?

38. What would be the weight in ℥ of 2 O. of diluted alcohol, sp. gr., .93?

Reducing Weight to Volume.

1. Grammes to Cubic Centimeters or Mils.

As was explained on page 55, the specific gravity expresses the weight in Grammes of one cubic centimeter. Thus the expression, glycerin, sp. gr., 1.25, means that each cubic centimeter of glycerin weighs 1.25 Gm. Then 1.25 Gm. of glycerin will measure 1 cubic centimeter; 2.5 Gm. of glycerin will measure 2 cubic centimeters; and 50 Gm. of glycerin will measure as many cubic centimeters as 1.25 Gm., the weight of 1 cubic centimeter, is contained in 50 Gm.

Hence the rule—

Wt. in Gm. ÷ sp. gr. = vol. in c.c. (mils).

Problems.

39. A solution of ferric sulphate has a sp. gr. of 1.32. Calculate volume of 358.5 Gm. Ans. 271.59 c.c.

40. A formula calls for 246 Gm. of nitric acid, sp. gr., 1.4. But on account of the corrosive action of the acid on the balances, it is much more convenient to *measure* the acid than to weigh it. How many c.c. should be used?

41. A formula calls for 870 Gm. of sulphuric acid, sp. gr., 1.826. How many c.c. should be used? Ans. 476 c.c.

42. In making ferric chloride, 300 Gm. of hydrochloric acid is to be used. The acid having a sp. gr. of 1.16, how many c.c. should be measured out?

43. A certain solution having a sp. gr. of 1.4, is directed to be given in 2 Gm. doses. What would be the dose in mils?

[In Europe it is customary to compound all medicines, liquids as well as solids, by weight. It is also customary to state the dose in weight units.]

44. A certain tincture is directed to be given in 3 Gm. doses. It has a sp. gr. of .86. What should be the dose in ♏?

45. In a certain formula 1 ℥ of nitric acid, sp. gr., 1.403, is required. How many c.c. should be used?
Suggestion.—Reduce 1 ℥ to Gm.; then to c.c.

46. A certain formula calls for 1 Kg. of phosphoric acid, sp. gr., 1.71. How many c.c. should be used?

47. A formula calls for 5 oz. of nitric acid, sp. gr., 1.4. How many c.c. should be used?

2. Grains to Fluid Ounces.

As has been shown on page 56, the weight of 1 fl. ounce of any liquid may be calculated if the specific gravity is known,, this being used as a multiplier for 454.6 gr., the weight of 1 fl. ounce of water.

Then, if the weight of 1 fl. ounce of the liquid is known, any given weight can be reduced to fl. ounces by dividing the given weight by the weight of 1 fl. ounce.

This may be expressed as follows:

Wt. of liquid in gr. ÷ (454.6 gr. × sp. gr.) = vol. in f ℥.

[And, since multiplying the divisor is the same as dividing the dividend, the no. of f ℥ may be found also by dividing the weight of the liquid in gr. first by 454.6 gr., then by the sp, gr.

Wt. of liquid in gr. ÷ 454.6 gr. ÷ sp. gr. = vol. in f℥.

Problems.

48. Calculate the volume in f ℥ of 1 lb. of commercial ether, sp. gr., .725.

Solution.—

1 lb. = 7000 gr.

454.6 gr. × .725 = 328.6 gr.

wt. 1℥ of water × sp. gr. = wt. of 1 f℥ of ether.

Then, 7000 gr. ÷ 328.6 (gr.) = 21.3. (Ans.)

(wt. given) ÷ (wt. of 1 f ℥) = no. of f ℥.

49. Find volume in f ℥ of 1 lb. of water.

50. Find volume in f ℥ of 1 lb. of chloroform, sp. gr., 1.48. Ans. 10.4 f ℥.

51. Find volume in f ℥ of 1 lb. of mercury, sp. gr., 13.5.

52. Find volume in f ℥ of 1 lb. of oil of lemon, sp. gr., .858. Ans. 17.9 f ℥, or 17 f ℥ 7 f ʒ 12 ♏.

53. Find volume in f ℥ of 5℥ 3ʒ 1 ℈ 10 gr. of solution of ferric chloride, sp. gr., 1.3.

54. Find volume in pints of 5 lb. of nitric acid, sp. gr., 1.4.

55. Find volume in c.c. of 4 lb. of hydrochloric acid, sp. gr., 1.158. Ans. 1568 c.c.

56. Find volume in L. of 50 lb. of glycerin, sp. gr., 1.25.

57. Find volume in pints of 25 Kg. of glycerin, sp. gr., 1.25. Ans. 42.26 pints.

58. One pound (av.) of ether, sp. gr., .716 would fill how many 2 f ℥ bottles? Ans. Nearly 11.

59. One hundred pounds of mercury, sp. gr., 13.53 would fill how many pint bottles? Ans. 7.11 pints.

60. How many fl. ounces in 2 Kg. of chloroform, sp. gr., 1.48? Ans. About 45.

61. A carboy of stronger ammonia water, sp. gr., .9, contains 115 lb. of the water. How many pints does it contain? How many Liters?

62. A carboy of sulphuric acid, sp. gr., 1.8 contains 142 Kg. How many cubic centimeters does it contain? How many fl. ounces? How many Liters? How many gallons?

63. A druggist buys glycerin, sp. gr., 1.25, at 45c. per lb. and sells a pint at 80c. What is his profit on each pint?

64. A druggist buys chloroform, sp. gr., 1.48 at 70c. per lb., and sells a Liter for $2.00. Does he gain or lose? How much? Ans. He loses 28.2c.

3. Grains to Minims.

Since 1 ♏ of water weighs .95 gr., .95 gr. multiplied by the sp. gr. gives the weight in gr. of 1 ♏ of any liquid and—

No. of gr. given ÷ (.95 gr. × sp. gr.) = vol. in ♏.*

*Or, No. of gr. given ÷ .95 gr. ÷ sp. gr. = vol. in ♏.

65. Find volume in minims of 200 gr. of c.p. chloroform, sp. gr., 1.49.

Solution.— .95 gr. × 1.49 = 1.4155 gr.

(Wt. of 1 ♏ of water) × (sp. gr.) = (wt. of 1 ♏ of chloroform.)

Then— 200 gr. ÷ 1.4155 gr. = 141. (Ans.)

No. of gr. given ÷ wt. of 1 ♏ = No. of ♏.

66. Find volume in minims of 90 gr. of lactic acid, sp. gr., 1.2. Ans. 79 ♏.

4. Drachms and Ounces to Fluid Drachms and Fluid Ounces.

As was explained on page 58, 1 f ʒ of water weighs about .95 ʒ; and 1 f ℥ of water, about .95 ℥.

Then—,No. of ʒ given ÷ (.95 ʒ × sp. gr.) = vol. in f ʒ; and No. of ℥ given ÷ (.95 ℥ × sp. gr.) = vol. in f ℥.

The answers will be slightly high, but sufficiently accurate for practical purposes. The student should explain why these answers are slightly higher than answers obtained by rules on page 60.

67. Find volume in f ʒ of 6 ʒ of bromine sp. gr., 2.99.

68. Find volume in f ℥ of 8 ℥ of phosphoric acid, sp. gr., 1.71. Ans. 4.9 f ℥, or 4 f ℥ 7 f ʒ 21 ♏.

69. Find volume in c.c. of 8 ℥ of phosphoric acid, sp. gr., 1.71. Ans. 147.7 c.c.

70. Find volume in f ℥ of 250 Gm. of phosphoric acid, sp. gr., 1.71.

5. Imperial Ounces to Fluid Ounces.

An Imperial or avoir. oz. of water measures an Imperial fluid ounce. Hence— No. of Imp. oz. ÷ sp. gr. = Imp. fl. oz.

71. Find volume in Imp. fl. oz. of 10 Imp. oz. of glycerin, sp. gr., 1.25. Ans. 8 Imp. fl. oz.

CHAPTER IV.

REDUCING AND ENLARGING FORMULAS.

Let us suppose that just 25 Gm. of compound morphine powder is wanted. The formula to be used is that of the U. S. P., 1890, as follows:

Morphine sulphate.........	1 Gm.
Camphor	19 Gm.
Glycyrrhiza	20 Gm.
Precip. calcium carbonate...	20 Gm.
To make................	60 Gm.

Now 25 Gm. is $\frac{25}{60}$ of 60 Gm. So we must multiply the quantity for each ingredient by $\frac{25}{60}$, in order that the mixture may weigh 25 Gm. in place of 60 Gm. That is, we must divide by 60, which would give us the amount to be used for 1 Gm. of powder, and then multiply by 25, because we wish to make 25 times 1 Gm., namely, 25 Gm.*

From the above reasoning we may deduce the following general rule:

To reduce or enlarge a formula, multiply the quantity of each ingredient by a fraction of which the quantity [of the preparation] to be made is the numerator, and the quantity the formula makes is the denominator. In practice this fraction is always reduced to the simplest expression; $\frac{30}{60}$ becomes $\frac{1}{2}$; $\frac{25}{60}$ becomes $\frac{5}{12}$; $\frac{600}{1000}$ becomes $\frac{6}{10}$ or .6.

Problems.

1. How much vinegar of squill, and how much sugar are required to make 600 mils of syrup of squill?

Formula:

Vinegar squill	450 mils
Sugar	800 Gm.
Water q. s. ad	1000 mils

* In practice cumbersome fractions are to be avoided when possible. The practical druggist would make 30 Gm. in place of 25; and since $\frac{30}{60} = \frac{1}{2}$, would avoid the lengthy calculation, and save enough time to compensate for the extra 5 Gm. of powder, should the latter be wasted.

The formula is for 1000 c.c., but we wish to make 600 c.c., which is $\frac{600}{1000}$ or .6 of 1000 c.c.

Hence each quantity must be multiplied by $\frac{600}{1000} = .6$.

Operation:

450 c.c $\times$ .6 = 270 c.c.
800 Gm. $\times$ .6 = 480 Gm.
1000 c.c. $\times$ .6 = 600 c.c.

2. How much iodine is required to make 1 pint of a tincture, a Liter of which contains 70 Gm. of the constituent?

Solution.— 1 O. = 16 f ℥; and 1 f ℥ = 29.57 c. c.

Accordingly 1 O. = (16 $\times$ 29.57) = 473 c.c.

Then 70 Gm. $\times$ $\frac{473}{1000}$ [or .473] = 33.11 Gm., the amount of iodine for 1 pint.

3. Calculate the quantities for 1 gallon of soap liniment from the following formula:—soap, 60 Gm.; camphor, 45 Gm.; oil rosemary, 10 c.c.; alcohol, 725 c.c.; water, q. s. ad 1000 c.c.

4. Calculate the formula for 1 Kg. of tooth powder from the following formula:—Powdered soap, 4 oz.; precip. chalk, ½ lb.; camphor, 30 gr.; vanillin, 5 gr.; oil rose, 8 ♏; powdered sugar, 2 oz.; magnesium carbonate, q. s. ad 1 lb.

Solution.—1 Kg. = 2.2 lb. Hence each quantity is to be multiplied by $\frac{2.2}{1}$ that is, by 2.2.

4 oz. $\times$ 2.2 = 8.8 oz. = 249.48 Gm.
½ lb. $\times$ 2.2 = 1.1 lb. = 500 Gm.
30 gr. $\times$ 2.2 = 66 gr. = 4.29 Gm.
5 gr. $\times$ 2.2 = 11 gr. = .715 Gm.
8 ♏ $\times$ 2.2 = 17.6 ♏ = 1.08 c.c.
2 oz. $\times$ 2.2 = 4.4 oz. = 124.74 Gm.

Mag. carb. q. s. ad 2.2 lb. = q. s. ad 1 Kg.

Note.—Remember that the product is always in the same unit as the multiplicand.

5. The National Formulary gives the following formula for Dewee's Carminative:—magnesium carbonate, 50 Gm.; tr. asafoetida, 75 c.c.; tr. opium, 10 c.c.; sugar, 100 Gm.; water, q. s. ad 1000 c.c.

(a.) Calculate quantities for 120 c.c.; (b.) for 4 f℥; (c.) for ½ Cong.; (d.) for 2 L.; (e.) for 3750 c.c.

6. The formula for compound syrup of squill is:—fl. ext. squill, 80 c.c.; fl. ext. senega, 80 c.c.; antimony and potassium tartrate, 2 Gm.; purified talcum 20 Gm.; sugar, 750 Gm.; water, q. s. ad 1000 c.c.

(a.) Calculate quantities for 1 O.; (b.) 180 c.c.; (c.) for 1 Cong.; (d.) for 5850 c.c.; (e.) for 2 O. 6 f℥.

7. A formula for deep blue show globe color is:—copper sulphate, 15.5 Gm.; water, 250 c.c. Make solution, to which add—ammonia water, 75 c.c.; and then enough water to make 2 L.

(a.) Calculate formula for 5780 c.c. (b.) for 2 gallons. Ans. Copper sulphate, 58.67 Gm., water, 946 c.c., ammonia water, 283.9 c.c; and enough water to make 2 gallons.

Calculating Definite Weight from Parts by Weight.

"Parts-by-weight-formulas" are given in the U. S. Pharmacopoeia of 1880, in the latest edition of the German Pharmacopoeia (1900), in the National Formulary, and in many scientific publications.

The advantage of such a formula lies in the fact that a part may mean a pound, an ounce (av.), an ounce (apoth.), a grain, a Gramme, a Kilogramme,—in short, any convenient unit of weight. But for formulas for liquids, "parts by weight" were never popular in the United States, because of the established custom in our country of *measuring* liquids.

Problems.

8. Calculate a formula for 5 lb. of salicylated talcum from the following formula of the German Pharmacopoeia of 1900:—salicylic acid, 3 parts; wheat starch, 10 parts; talcum, 87 parts.

Solution.—A part in this case is assumed to be a pound. Then the general rule, to multiply each quantity by the fraction of which the amount wanted is the numerator, and the amount the formula makes is the denominator, is applied. The amount wanted is 5 lb.; the formula makes 100. Hence each quantity is multiplied by $\frac{5}{100}$ or .05.

Thus we have—

Salicylic acid	3 lb. × .05 = .15 lb.
Wheat starch	10 lb. × .05 = .5 lb.
Talcum	87 lb. × .05 = 4.35 lb.

The fractions of pounds should, of course, be reduced to lower units.

9. Suppose 500 Gm. of the salicylated talcum are wanted. Each part is assumed to be a Gramme. Then—

$$3 \text{ Gm.} \times \frac{5\cancel{00}}{1\cancel{00}} = 15 \text{ Gm.}$$
$$10 \text{ Gm.} \times 5 = 50 \text{ Gm.}$$
$$87 \text{ Gm.} \times 5 = 435 \text{ Gm.}$$

10. Suppose 480. gr. are wanted for a prescription. Each part is assumed to be a grain. Then—

$$3 \text{ gr.} \times \tfrac{480}{100} = 14.4 \text{ gr.}$$
$$10 \text{ gr.} \times 4.8 = 48. \text{ gr.}$$
$$87 \text{ gr.} \times 4.8 = 417.6 \text{ gr.}$$

11. The German Pharmacopoeia of 1900 gives the following formula for powder of magnesia and rhubarb:—magnesium carbonate, 50 parts; eleosaccharate of fennel oil, 35 parts; rhubarb, 15 parts. (a.) Calculate quantities for 600 Gm. of the powder; (b.) for 2 Kg.; (c.) for 2 lb.; (d.) for 8 ℥; (e.) for 8 oz.; (f.) for 300 gr.; (g.) for 6 ℥ 2 ʒ 1 ℈ 10 gr.

Ans.	(a.)	(d.)	(e.)
Mag. carb.	300 Gm.	4 ℥	4 oz.
Eleosacch. of fennel	210 Gm.	2 ℥ 6 ʒ 1 ℈ 4 gr.	2 oz. 350 gr.
Rhubarb	90 Gm.	1 ℥ 1 ʒ 1 ℈ 16 gr.	1 oz. 87½ gr.

12. Recipe for polishing paste:—oxalic acid, 1 part; jewelers' rouge, 16 parts; rotten stone, 20 parts; palm oil, 59 parts; petrolatum, 4 parts. (a.) Calculate formula for 1 lb.; (b.) for 1 Kg.; (c.) for 12 oz.; (d.) for 400 Gm.

CHAPTER V.

Proportions.

To solve the problem—If 20 lb. of tartaric acid cost \$7, how much will 32 lb. cost?—we reason as follows:—1 lb. of acid will cost $\$7.00 \div 20 = \$.35$; and 32 lb. will cost 32 times as much as 1 lb., hence $\$.35 \times 32 = \$11.20$.

We may arrive at the same answer by an operation based upon a different line of reasoning, thus:—Price and quantity in this problem bear such a relationship to each other that they increase and decrease in the ratio. If, for instance, the quantity is doubled, is raised to 40 lb., the price must be doubled likewise, must be raised to \$14.00. Notice that the increase is not dollar per pound, *but at the same rate* in case of the dollars as in case of the pounds. If the quantity is reduced to one-fourth, to 5 lb., the price becomes $\$7.00 \div 4 = \$1.75$. Then if we can find the ratio of 20 lb. to 32 lb., we have also the ratio of \$7.00 to the answer sought.

When this definite relationship exists between values—when they increase and decrease in the same ratio—the values are said to be proportional to each other. Thus quantities and prices are proportional.

The statement that 20 lb. bears the same relation to 32 lb. as \$7.00 bears to \$11.20, is called a statement of a proportion. The statement may be more concise as follows.—

20 lb. is to 32 lb., as \$7.00 is to \$11.20.

For *is to*, it is customary to use the sign of ratio, the colon [:]; and for *as*, the sign of proportion, the double colon [: :]. Thus—

20 lb.	:	32 lb	::	\$7.00	:	\$11.20.
	is to		as		is to	

Each one of the members of the proportion is called a term. Terms are numbered from left to right. Thus in the preceding example 20 lb. is the *first* term, 32 lb., the *second* term, \$7.00, the *third* term, and \$11.20, the *fourth*.

The first two terms constitute the *first couplet*, and the last two, the *second couplet*.

The first and last terms are called the *extremes*; the second and third, being in the middle, are called the *means.*

1st couplet				2nd couplet		
20 lb.	:	32 lb.	: :	\$7.00	:	\$11.20
1st term		2nd term		3d term		4th term
		means				
extremes						

It will be seen that the product obtained by multiplying the two means, and the product obtained by multiplying the two extremes are the same.

$$20 \times 11.20 = 224.00$$
$$32 \times 7.00 = 224.00$$

It follows that the product of the extremes divided by either mean will give the other mean. And the product of the means divided by either extreme will give the other extreme.

$$224 \div 20 = 11.20;\ 224 \div 11.20 = 20$$
$$224 \div 32 = 7.00;\ 224 \div 7.00 = 32$$

Hence if three terms are known, the fourth one may be calculated.

The missing term may be any one of the four, as follows:

1. If 20 lb. of acid cost \$7.00, how many lb. of acid may be bought for \$11.20?
2. If 32 lb. cost \$11.20, how many lb. could be bought for \$7.00?
3. If 20 lb. cost \$7.00, how much would 32 lb. cost?
4. If 32 lb. cost \$11.20, how much would 20 lb. cost?

The preceding four problems may be stated thus:

1.	x	:	20 lb.	::	\$11.20	:	\$7.00
2.	32 lb.	:	x	::	\$11.20	:	\$7.00
3.	32 lb.	:	20 lb.	::	x	:	\$7.00
4.	32 lb.	:	20 lb.	::	\$11.20	:	x

And solved thus:

1 and 4. Multiply the two means, and divide by the given extreme.

2 and 3. Multiply the two extremes, and divide by the given mean.

It is, however, simpler and less apt to lead to error, if the proportion be always so stated that the missing term is the fourth.

This can be done by applying the following rules:

1. Let the 3d term be that number which expresses the same kind of value as will be expressed by the answer sought.

2. Then decide whether the answer sought is to be greated or smaller than this 3d term. If greater, place the greater of the two remaining terms as the 2nd term; if smaller, place the smaller of the two remaining terms as the second.

3. The remaining known term place as the first.

Note.—The 1st and 2nd terms must be in the same unit of value, in order that the ratio of the abstract numbers may also be the ratio of the denominate numbers.

Since the missing term is one of the extremes, it is obtained by multiplying the two means—the 2nd term and the 3d—and dividing the product by the 1st term*.

Note.—The answer will be in the same unit as the 3d term. If it is to be in a different unit it must subsequently be reduced to that unit.

Problem.—If 437.5 gr. (1 oz.) of phenacetine cost 95c, how much will 120 gr. (2 ℨ) cost?

Solution.—The three known terms are—95c, 437.5 gr., 120 gr. The answer will express cost. i. e., money-value. Therefore the known term expressing cost should be the third term:

: :: 95c : x (Answer.)

Since the quantity for which the cost is to be found is less than the quantity for which the price is given, the answer will be smaller than the third term. Hence the smaller of the two remaining terms is to be the second:

: 120 gr. :: 95c : x

As but one known term remains unplaced, this must be the first:

---

*This is identical with dividing the known term of the second couplet by the ratio of the 1st term to the 2nd.

437.5 gr. : 120 gr. :: 95c : x

The 1st and 2d terms may now be treated as abstract numbers:

95c × 120 = 11400c
11400c ÷ 437.5 = 26c. (Answer.)*

Solving the problem by analysis, we would reason thus: —if 437.5 gr. cost 95c, 1 gr. will cost 95c ÷ 437.5; and 120 gr. will cost 120 times as much as 1 gr. In this case the division is carried out first, and the quotient is multiplied, while in the proportion the multiplication is carried out first and the division last. One of the fundamental rules of arithmetic is that multiplication and division may be carried out in any order. So a proportion could be completed by dividing the first term into the second or third, and then multiplying the remaining known term by the quotient. But it is preferable to carry division out last—not only in proportions, but in all problems—for the reason that the quotient may be burdened with an interminate decimal, the rounding off of which occasions an error, an error that a subsequent multiplication would magnify.

Problems.

1. If cocaine costs $6.50 an oz., how much will 3 ʒ cost?

Solution.—The three known terms are: $6.50, 1 oz., ond 3 ʒ. The answer is to express cost. Hence—

: :: $6.50 : x

The 1st and 2d terms must be in the same unit. In this problem the 1 oz. and the 3 ʒ are best reduced to gr.

1 oz. = 437.5 gr., and 3 ʒ = 180 gr. [If the cost were known per ℥, it would be simpler to reduce to ʒ.]

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*Cancellation.

The figuring may frequently be lessened by cancellation. That is, by dividing the first term by a certain number, and then one of the other terms by the same number, which process in no way changes the ratios.

Example,—

$$\begin{array}{ccccccc} 3 & & 91 & & & & \\ \cancel{270} & : & \cancel{819} & :: & 35\cancel{0} & : & x \end{array}$$

The first term and also the third may be divided by 10 by cancelling the ciphers. Then the first term and the second may each be divided by 9. The work has now been simplified to 91 × 35 ÷ 3.

In proportions stated so that the unknown term is the fourth, the second and third terms are multiplied, one with the other, and hence cannot be cancelled against each other.

The quantity for which the cost is to be found is smaller than the quantity for which cost is given. Hence the answer will be smaller—

437.5 gr. : 180 gr. : : \$6.50 : x

\$6.50 × 180 = \$1,170.00; \$1,170.00 ÷ 437.5 = \$2.67.

2. (a.) If cocaine costs \$6.50 an oz., how much will 2 ʒ 1 ℈ 5 gr. cost? (b.) How much will 2 Gm. cost? (c.) How much will 3.256 Gm. cost? Ans. (c.) 74c.

3. (a.) If chloral hydrate costs \$1.30 a lb., how much will 1 ℥ cost? (b.) How much will 10.560 Gm. cost?

4. (a.) If cream of tartar costs 60c per Kg. (Kilo.), how much will 1 lb. cost? (b.) How much will 1 ℥ cost? (c.) How much will 2¾ oz. cost? (d.) How much will 2 ℥ 2 ʒ 2 ℈ 2 gr. cost? Ans. (a.) 27c.

5. If homatropine costs \$6.00 a Gm., how many gr. can be bought for \$1.75? Ans. 4½ gr.

Remarks.—The answer is to express quantity; hence 1 Gm. is the 3d term. The answer will be in Gm., and must be reduced to gr.

6. If homatropine costs \$6.00 a Gm., how much would 2 gr. cost? Ans. Nearly 78c.

7. If 15 gr. of heroin cost 18c, how much is 1 oz. worth?

8. (a.) If alcohol costs \$2.40 a gallon, how much does a Liter cost? (b.) How much would 225 c.c. cost? (c.) How much would 2 O. 6 f ℥ cost? (d.) How much can be bought for \$100?

9. Glycerin cost 23c per lb. Its sp. gr. is 1.25. How much does it cost a Liter?

Solution.— 1 L. = 1000 mils;

1000 × 1.25 (sp. gr.) = 1250 Gm.

1 lb. = 453.6 Gm.

Then 453.6 Gm : 1250 Gm. : : 23c : (x) 67.8c

Note.—Quantity is proportional to price; and the quantity may be expressed in weight or volume, and in any unit of these, provided the 1st and 2d terms are in the same unit. So this and similar problems may be solved in several different ways.

10. Oil of lemon costs \$1.25 a lb., and has a sp. gr. of .855. How much does it cost per f℥? Ans. 7c.

11. (a.) Mercury costs \$1.50 per Kg. Taking its sp.

gr. as 13.5, how much would 4 f ℥ cost? (b.) How much would 12 c.c. cost? (c.) How much would 2 f ʒ 45 ♏ cost?

12. Alcohol costs $2.40 a gal., and has a sp. gr. of .81. How much does it cost per lb.? Ans. 35.6c.

13. Castor oil costs 14c. a lb., and has a sp. gr. of .95. How much does it cost a gal? Ans. $1.10.

14. Chloroform costs 60c. a lb., and has a sp. gr. of 1.48. How many f ℥ can be bought for 75c? Ans. 13 f ℥.

15. If 4 Gm. of mustard will make 60 square centimeters of mustard paper (plaster), how much mustard should be spread on a plaster 3 in. by 4 in.?

Solution.—3 in. by 4 in. = 7.6 cm. by 10.2 cm.; and 7.6 cm. × 10.2 cm = 77.52 sq. cm.

Then 60 sq. cm. : 77.52 sq. cm. : : 4 Gm. : x (5.166 Gm.)

16. If 1 gal. of paint costs $1.35, and will cover 500 sq. ft., what would be the cost of 3 coats for a house 18 ft. high 30 ft. broad, and 45 ft. long?

Remarks.—The relationship between price and quantity, or between quantity of paint and amount of surface to cover, as in problem 16, is clearly seen, and that these values are proportional is quite obvious. But in many pharmaceutical problems the relationship is not so apparent, or, may appear to exist when it does not. In the appendix is given a list of proportional values, which list should be frequently consulted.

Certain values bear such a relationship to each other that one increases in the some ratio in which the other decreases. Values proportional in this sense are said to be inversely proportional. See Chapter VII.

TRADE DISCOUNT.

Problems involving interest, profit and loss, premiums, discount, as well as all other percentage problems, may be solved without the use of specific rules, if the general directions for stating proportions are observed.

It should be remembered, however, that if several discounts are given, the second is based not upon the regular selling price, but upon the price obtained by deducting the first discount; that the third is based upon the price obtained by deducting the first and second discounts; etc.

Problem.—Certain apparatus is quoted at $120.00 per gross, with 40%, and 10% off, and an additional discount of 3% for cash. What is the net cost?

Solution.— 40% of $120.00 = $48.00; $120.00 minus $48.00 = $72.00.

10% of $72.00 = $7.20; $72.00 minus $7.20 = $64.80

3% of $64.80 = $1.94; $64.80 minus $1.94 = $62.86 (Ans.)

CHAPTER VI.

PERCENTAGE PROBLEMS.

Percentage—abbreviated percent., and indicated by the symbol %—means parts per 100 parts.

Opium, said to contain 14% of morphine, contains 14 parts of the latter to 86 parts of other constituents, making 100 parts in all.

The amount of a constituent in a drug, the amount of component in a mixture or in a preparation, the amount of dissolved substance in a solution,—all these amounts are conveniently expressed in percentages; that is, they are conveniently adjusted to the scale of 100*.

This being true, problems involving percentages are of frequent occurrence in every-day work.

In such problems the following factors come into play:

1. The amount of drug, mixture, preparation, or solution, or whatever is to represent the 100 parts.

2. The amount of constituent or ingredient.

3. The amount of constituent or ingredient as expressed in percentage.

4. The amount of drug, mixture, etc., expressed in percentage. This is always 100, and is never sought as an answer.

5. The amount of diluent or solvent.

For sake of brevity let us designate drug, mixture, preparation, or solution by M, standing for mixture; constituent or ingredient by C, standing for constituent; percentage by its customary symbol, %; and diluent or solvent by D.

In percentage problems there are four cases possible: (1) M may be sought, the other factors being known; (2)

*In order that comparisons may be readily made—made by inspection—such data should be reduced to *some* common standard or scale; and the number 100 is selected, rather than 12, 144, or any other number, for arithmetical reasons.

C may be sought; (3) % may be the element to be calculated; (4) the amount of diluent or solvent may be sought.

It should be remembered that percentages in pharmaceutical or chemical problems refer to parts *by weight,* unless the contrary is expressly stated. Now, if percentages stand for parts by weight, they are proportional to weights of M and of C, and any one of the first three factors—M, C, or %—may be calculated by proportion.

D is the difference between C and M, and is found by subtracting C from M. See page 79.

Examples.

1. Suppose that 6 Gm. of opium on analysis are found to contain .585 Gm. of morphine, and the morphine-strength of the opium is to be expressed in percentage.

Solution:—

The three known terms are:—6 Gm. (amount of drug = M), .585 Gm. (amount of morphine, i. e., constituent = C), 100 per cent. (per cent of M)*.

The missing term is per cent. of C.

Since the answer is to be in per cent., the known per cent., 100 per cent. (M is always assumed to be 100 per cent.), must be the third term.

: :: 100 per cent. : x

The answer is to be smaller than 100 per cent. because the amount of C. (.585 Gm.) is smaller than the amount of M (6 Gm.). Or, to generalize, the per cent of C must always be less than 100, because a part is less than the whole. Therefore the smaller of the two remaining known terms is the second, and the larger, the first.

6 Gm. : .585 Gm. : : 100 per cent : x

x = 9.75 per cent.

2. How much morphine is present in 60 Gm. of opium having a morphine-strength of 12%?

The three known terms are:— 60 Gm. (amount of M), 12 per cent. (per cent. of C), and 100 per cent. (per cent. of M).

*Remember that M always stands for the medicinal substance or preparation in its totality. So in this and the immediately succeeding problems it stands for opium, and not for morphine, although the latter word begins with *m*. The choice of drug and constituent might *appear* unfortunate; but the selection of a constituent with a name beginning with *m* was premeditated, the object being to point out that the symbols M and C are general, and have no relationship to the names of specific drugs, or of preparations, or of constituents.

The answer is to express weight. Therefore—

: :: 60 Gm. : x

The answer is to be smaller than 60 Gm., because 12 per cent is less than 100 per cent. And because C, the part must weigh less than M, the whole.

Then the smaller remaining term (12 per cent.) must be the second. Thus—

100 per cent : 12 per cent : : 60 Gm. : x
x = 7.2 Gm.

3. If a certain opium has a morphine-strength of 14%, how much of the opium would contain just 5 Gm. of morphine?

The known terms are:— 100 per cent. (per cent. of M), 14 per cent. (per cent. of C), and 5 Gm. (wt. of C).

The term sought is wt. of M.

Since the answer is to be in weight, the known weight is the third term.

: :: 5 Gm. : x

The answer is to be greater, because 100 per cent, is greater than 14 per cent. and because the whole must be greater than the part. Hence—

14 per cent. : 100 per cent. : : 5 Gm. : x
x = 35.714 Gm.

While the rules on page 69 for stating proportions are always applicable, and cannot mislead, it is well to know that in percentage proportions correctly stated, M and C alternate; that is, the term giving % of M and the one giving weight of M are never side by side, but have another term between them,—which is true likewise, for the two terms giving respectively weight and % of C.

Observe the three proportions just given.

1. 6 Gm. : .585 Gm. : : 100% : (x) 9.75%
wt. of M. wt. of C. % of M. % of C.

2. 100% : 12% : : 60 Gm. : (x) 7.2 Gm.
% of M. % of C wt. of M. wt of C

3. 14% : 100% : : 5 Gm. : (x) 35.714 Gm.
% of C % of M wt. of C wt. of M..

N. B.—A similar alternation occurs in all proportions in which the two values are *directly* proportional; if they are inversely proportional [see chapter VIII] the alternation does not occur.

Other Arithmetical Processes.

Problem 1 may be solved also by reasoning as follows: If 6 Gm. of opium contain .585 Gm. of morphine, 1 Gm. of opium will contain .585 Gm. ÷ 6 = .0975 Gm.; and 100 Gm. will contain 100 times as much as 1 Gm., hence [.0975 Gm × 100 =] 9.75 Gm.

Consequently the answer is, 9.75 per cent.

Formulating this we have—

$$\% = (C \div M) \times 100 \quad \text{or,}\ \% = \frac{C \times 100}{M}$$

Problem 2 is solved as follows: If the morphine strength of the opium is 12 per cent., each 100 Gm. of the latter contain 12 Gm. of morphine, and 1 Gm. of opium contains 12 Gm. ÷ 100 = .12 Gm. Then 60 Gm. contain 60 times as much as 1 Gm., that is [.12 Gm. × 60 =], 7.2 Gm.

Expressing the above process in a formula, we have—

$$C = (\% \div 100) \times M \quad \text{or,} \quad C = \frac{\% \times M}{100}$$

Problem 3: If the morphine-strength of the opium is 14 per cent., 100 Gm. of the latter contain 14 Gm. of morphine. Then 1 Gm. of morphine will be contained in [100 Gm. ÷ 14 Gm. =] 7.1428 Gm. of opium; and 5 Gm. of morphine will be contained in 7.1428 Gm. × 5 = 35.714 Gm.

This expressed in a formula gives:

$$M = (100 \div \%) \times C \quad \text{or,}\ M = \frac{100 \times C}{\%}$$

The same result may be obtained as follows: In 100 Gm. of opium there are 14 Gm. of morphine. In 1 Gm. of opium there are

14 Gm. ÷ 100 = .14 Gm. of morphine. Then the answer will be: as many Gm. of opium as .14 Gm. is contained in 5 Gm. = 35.714 Gm.

Formula—

$$M = C \div \% \div 100.$$

Since dividing the divisor is the same as multiplying the dividend,

$$\frac{100 \times C}{\%} = C \div \% \div 100,$$

and the two processes must give the same answer;—must both be correct.

ADVICE TO STUDENTS.

The formulas in the preceding paragraphs should not be memorized, and followed blindly. Students who cannot solve percentage problems by a process of reasoning, are strongly advised to avoid all formulas and rules (which are usually remembered imperfectly), and to solve all such problems by proportion. The principles underlying proportions are soon mastered by the average students; and by the exceptional ones, who are absolutely unmathematical, the process may be followed empirically without danger of error, as, in proportions, no matter what the case—no matter which factor is missing—the rules to be followed are the same. (See page 69).

Problems.

4. A certain drug contains 17% of soluble matter, hence will yield 17% of extract. How much extract could be obtained from 500 Gm. of the drug? Ans. 85 Gm.

5. How many lbs. of the same drug would be required to make 5 lbs. of extract? Ans. $29\frac{7}{17}$ lb.., or 29.41 lb.

6. What is the percent. of extractable matter in a certain licorice root, 500 Gm. of which yield 90 Gm. of extract?

7. Diluted hydrocyanic acid, U. S. P., contains 2% of absolute hydrocyanic acid (HCN), the remainder being water. How much absolute acid in 450 Gm.? Ans. 9 Gm.

8. Official nitric acid contains 68% of absolute nitric

acid (HNO_3), the remaining 32% being water. How many gr. of absolute HNO_3 in 400 gr.? Ans. 272 gr.

9. How many Gm. of iodine in 300 Gm. of a 5% solution?

10. How much iodine should be weighed out to make 1 Kg. of a 5 % solution?

11.. How many Gm. of 5% soda solution can be made from 400 Gm. of soda?

12. What is the percentage strength of a solution of homatropine made by dissolving 15 gr. in enough water to make 400 gr.? Ans. 3.75%.

13. What is the percentage strength of a solution of mercuric chloride made by dissolving 60 gr. of the latter in enough water to make 5,000 gr.?

14. What is the percentage strength of a solution of sodium chloride made by dissolving 65 gr. of the salt in 400 gr. of water?

Solution.— 65 gr. in 400 gr. would make 465 gr. of solution. The three known terms are: [400 + 65 =] 465 gr., 65 gr., 100 per cent. Percentage is asked for. Hence—

: : : 100% : x.

The answer is to be less than 100%. Hence—

465 gr. : 65 gr. :: 100% : (x) 13.9%

15. What is the percentage strength of a solution of carbolic acid in glycerin made by mixing 350 Gm. of the latter with 200 Gm. of the acid?

16. Boric acid is soluble in 18 parts of water. What is the percentage strength of a saturated solution?

Solution.— 1 part of acid + 18 parts of water = 19 parts of solution. Then 19 parts : 1 part :: 100% : x (5.26%).

17. Potassium chlorate is soluble in 16 parts of water. What is the per cent. strength of a saturated solution?

18. One part of water will dissolve 1.4 parts of potassium iodide. What is the per cent. strength of a saturated solution? Ans. 58.3%.

19. One part of water will dissolve $\frac{1}{18}$ part of po-

tassium permanganate. What is the per cent. strength of a saturated solution? Ans. 6.25%.

20. What percentage of sugar in a syrup made from 1 lb. of sugar and ½ lb. of water? Ans. 66 2-3%.

Calculating Amount of Diluent or Solvent.

To make 100 Gm. of a 15% solution of salt we may proceed in two ways: we may weigh out 15 Gm. of salt, and then add enough water to bring the total weight to 100 Gm.; or, we may add to the 15 Gm. of salt 85 Gm. of water, previously weighed. In the first method there is a possibility of adding too much water; and as solution begins at once, the excess of water cannot be removed without removing some salt also. For this reason the second method is preferred.

21. How many lbs. of sugar, and how many of water, are required to make 12 lbs. of syrup having a sugar-content of 65%?

Solution.— 100 per cent. : 65 per cent. :: 12 lbs. : x
x = 7.8 lbs. (wt. of sugar).

Then 12 lbs. — 7.8 lbs. = 4.2 lbs. (wt. of water).

22. In how many Gm. of water must 15 Gm. of cocaine hydrochloride be dissolved to make a 4% solution?

Solution.— 4 per cent. : 100 per cent. :: 15 Gm. : x
x = 375 Gm. (wt. of solution to be made).

Then 375 Gm. (weight of solution) minus 15 Gm. (wt. of cocaine) = 360 Gm. (wt. of water).

23. How many Gm. of magnesium sulphate, and how many Gm. of water, are required to make 600 Gm. of 28% solution? Ans. 168 Gm. mag. sulph. and 432 Gm. water.

24. How many oz. of carbolic acid, and how many of petrolatum, must be used to make 32 oz. of carbolated petrolatum containing 3% of carbolic acid?

25. How many Gm. of water must be used to dissolve 4 Gm. of mercuric chloride to make a $\frac{1}{10}$ % solution?

26. A certain nasal spray consists of liquid petrolatum, with 6% of menthol, 5% of eucalyptol, and 2% of thymol. How much must be used of each of the ingredients to make 150 Gm?

Solution.— 100% : 6% :: 150 Gm. : x
x = 9 Gm. (am't of menthol).

100% : 5% :: 150 Gm. : x
x = 7.5 Gm. (am't of eucalyptol).

100% : 2% :: 150 Gm. : x
x = 3 Gm. (am't of thymol).

Then 9 Gm. + 7.5 Gm. + 3 Gm. = 19.5 Gm. (am't of active ingredients);

And 150 Gm. (am't of spray) — 19.5 Gm. (am't of active ingredients) = 130.5 Gm. (am't of liquid petrolatum).

27.	℞	Iodoform	gr. xxx
		Boric acid	ʒ j
		Naphthalin	ʒ j

Make a fine powder, and flavor with 2% of oil of bergamot.

How much of the latter must be used? Ans. 3 gr.

28. How much oil, acacia and water are required to make the nucleus of 120 c.c. of a 40% emulsion. Sp. gr. may be ignored.

Solution.—By the continental method the nucleus is made of 4 parts of oil, 1 part of acacia, and 2 parts of water.

40 per cent of 120 c.c. = 48 c.c. (amount of oil).

Then if 4 parts = 48 c. c. (amount of oil),
2 parts = 24 c. c. (amount of water),
1 part = 12 Gm. (amount of acacia).

This nucleus is then to be diluted to 120 c.c., making a 40 per cent. emulsion.

Percentage Problems Involving Conversion from One System of Weight to Another.

29. How many Gm. of 4% solution can be made with 1 oz. of cocaine hydrochloride? Ans. 708.75 Gm.

30. What is the per cent. strength of a morphine sulphate solution made by dissolving ⅛ oz. in enough water to make 100 Gm? Ans. 3.543%.

31. To make 5 lbs. of 5% solution of soda, how many Gm. of the latter must be used?

32. How many Gm. of 2% atropine sulphate solution can be made with 1 ʒ 1 ℈ 10 gr.?

PROBLEMS INVOLVING ALSO REDUCTION OF VOLUMES TO WEIGHTS, OR WEIGHTS TO VOLUMES.

Since in these problems—and always when the contrary is not expressly stated—percentages stand for parts by weight, they are proportional to weights, *but not to volumes. If quantities* [of M or of C] *are given in volumes, these must be reduced to weights before employing the quantities as terms in proportions.* If the answers (4th terms) of these proportions represent quantities, these will be in weight—not in volume. So a conversion to volume must follow whenever the answer is to express volume.

33. Official nitric acid has a sp. gr. of 1.403, and contains 68% of absolute acid. How many Gm. of abs. acid in 2 L. of the official acid?

Solution.— 2 L. = 2000 c.c.

2000 × 1.403 (sp. gr.) = 2806. Hence 2000 c.c. = 2806 Gm.

Then 100% : 68% : : 2806 Gm. : x

x = 1908 Gm. (wt. of abs. acid).

34. Official solution of potassa has a sp. gr. of 1.046, and contains 5% of potassa. How many f℥ of solution could be made from 20 Gm. of potassa?

Solution.— 5% : 100% : : 20 Gm. : x

x = 400 Gm. (weight of solution).

400 ÷ 1.046 (sp. gr.) = 382.4 (vol. in c.c.)

382.4 ÷ 29.57 (c.c. in 1 f℥) = 12.93 f℥

35. Syrup contains 85 Gm. of sugar in 100 mils, and has a sp. gr. of 1.313. What per cent. of sugar does it contain?

Solution.—The sp. gr. being 1.313, 100 mils of syrup weigh 131.3 Gm.

Then— 131.3 Gm. : 85 Gm. :: 100% : x

$x = 64.7\%$

36. Stronger ammonia water has a sp. gr. of .897, and contains 28% of ammonia. How many Gm. of the latter in 1 pint of the stronger water? Ans. 118.8 Gm.

37. Official sulphuric acid has a sp. gr. of 1.826, and contains 92.5% of absolute acid. (a.) How many gr. of absolute acid in 1 f ℥ of official acid? (b.) How many Gm. of abs. acid in 2 L. of official acid? Ans. (a.) 769.7 gr.

38. A solution of ferric citrate has a sp. gr. of 1.25; and 1 L. yields 531.25 Gm. of ferric citrate (scale salt). What per cent. of ferric citrate in the solution?

39. In a certain chemical reaction 5 Gm. of absolute hydrochloric acid (HCl) is required. To supply it how many c.c. of official acid (sp. gr., 1.158, absolute-acid-content, 31.9%) must be used? Ans. 13.47 c.c.

40. 30 c.c. of ether, sp. gr., .716, is dissolved in enough alcohol to make 100 c.c. of solution, the latter having a sp. gr. of .8. What per cent. of ether (by weight) in the preparation?

41. Lead subacetate solution has a sp. gr. of 1.235, and contains 25% of lead subacetate. On diluting 3 c.c. of this solution to 100 c.c., diluted solution of lead subacetate (U. S. P. 1890) is obtained. How much lead subacetate does the latter solution contain in each f ℥?

Solution.—1 f ℥ = 29.57 c.c. If 100 c.c. of the diluted solution contain 3 c.c. of the strong solution, 1 c.c of the diluted solution will contain 3 c.c. ÷ 100 = .03 c.c. of the strong; and 29.57 c.c. of the diluted solution will contain .03 c.c. × 29.57. = .8871 c.c. of the strong solution. The sp. gr. of the latter being 1.235, the .8871 c.c. weighs [.8871 × 1.235 =] 1.0955 Gm. Of this 25% is lead subacetate. Then—

100% : 25% :: 1.0955 Gm. : (x) .274 Gm.

42. Solution of ferric sulphate has a sp. gr. of 1.432, and contains 36% of ferric sulphate. How many gr. of

ferric sulphate in 1 f℥ of a diluted solution, containing 20 c.c. of the official solution in 100 c.c.? Ans. 48 gr.

Volume Percentage.

A volume percentage solution is one having in 100 volumes a definite number of volumes of constituent, the latter necessarily being a liquid. Thus, alcohol, U. S., contains 94.9% by volume of absolute ethyl hydroxide, the remaining 5.1% by volume being water. Diluted alcohol, U. S., contains 48.9% by volume of ethyl hydroxide, and 51.1% by volume of water.

Notice that it is expressly stated that the percentage is by volume. When it is not so stated, weight percentage is always understood.

Since percentages in volume percentage stand for volumes, they are proportional to volumes just as weight percentages are proportional to weights. In other words, volume percentages are proportional to L., c.c., f ℥, ♏, etc., but not to weight units.

Problems.

44. In 1 gallon of an alcohol, containing 94% by vol. of ethyl hydroxide, there are how many f ℥ of the latter? Ans. 120.3 f ℥.

45. In 5 L. of diluted alcohol, containing 48.9% by vol. of ethyl hydroxide, there are how many c.c. of the latter?

46. A certain alcohol contains 6 O. 8 f ℥ of abs. ethyl hydroxide in each gallon. What % by vol. of ethyl hydroxide does the alcohol contain? Ans. 81.25% by vol.

47. A certain menstruum is to contain 15% by volume of glycerin. How much of the latter should a pint contain? Ans. 2 f ℥ 3 f ʒ 12 ♏.

Calculating Volume Percentage to Weight Percentage and Vice Versa.

If the sp. gr. of the constituent is known, and also the sp. gr. of the solution, volume percentage may be calculated to weight percentage,—and vice versa.

48. An alcohol, sp. gr., .82, containing 94% by volume of ethyl hydroxide contains what % by weight?*

Solution.—The sp. gr. of the alcohol [solution] is given as .82; that of ethyl hydroxide [constituent] as .79. If the sp. gr. of the alcohol is .82, 100 c.c. of it weigh 82 Gm. If the sp. gr. of the ethyl hydroxide is .79, 94 c.c. of it would weigh [94 × .79 =] 74.26 Gm.

Then—

82 Gm.	:	74.26 Gm.	::	100%	:	(x) 90.56%
wt of M	:	wt. of C	::	% by wt. of M	:	% by wt. of C

49. An alcohol is 91% strong by weight, and has a sp. gr. of .82. Calculate strength in volume percentage.*

Solution.— 100 Gm. of alcohol = 100 ÷ .82 = 121.9 c.c.
91 Gm. of ethyl hydroxide = 91 ÷ .79 = 115 c.c.

Then 121.9 c.c.	:	115 c.c.	::	100%	:	(x) 94 + %
vol. of M	:	vol. of C.	::	vol. % of M.	:	vol. % of C.

50. The sp. gr. of ethyl hydroxide being .79, what is the wt. per cent. strength of an alcohol of 66% by vol., and having a sp. gr. of .9?

51. An alcohol has a sp. gr. of .8719, and contains 70% by wt. of ethyl hydroxide [sp. gr. .7935]. What % by vol. of the latter does it contain?

[See alcohol table, U. S. P.]

Note.—By the Internal Revenue Office strength of alcoholic liquids is expressed by degrees proof. An alcoholic liquid containing 50 per cent. by vol. of absolute ethyl hydroxide is said to be 100 proof. An alcohol, 94 per cent. by vol. strong, is said therefore to be 188 proof. In short—degrees proof ÷ 2 = strength in per cent. by vol.; and per cent. by vol. × 2 = degrees proof.

52. What is the alcohol strength of brandy marked 110 proof?

Solution.— 110 ÷ 2 = 55% by vol.

*Answers to 48 and 49 will harmonize if specific gravities are not rounded off, as in the above solution.

To Calculate Amount of Constituent When the Sp. Gr. of Solution is Unknown.

Percentage, unless the contrary is expressly stated, refers to parts by weight. If the amount of constituent is to be calculated from the amount of solution, the weight of the latter must be known,—or must be calculated from the volume and the sp. gr., as in the problems on page 81.

In practice, however, the pharmacist is often called upon to dispense a definite volume of a solution of specified percentage strength but of unknown sp. gr. For instance, 1 f ℥ of a 4% solution of cocaine hydrochloride may be wanted.

Now, the error due to the assumption that the sp. gr. of such a low-strength solution is 1.000, would be very slight, and would be considered negligible by most physicians. But the doctrine of permissible inaccuracy is a dangerous one; and the student is not advised to take "short cuts" which affect the strength of a medicinal preparation. A solution of *exact* strength can be made as follows:

Use as large a volume of solvent as volume of product desired; and base calculation of amount of constituent upon the weight of this volume of solvent.

The constituent will augment the volume somewhat; if an exact volume is wanted, this may be measured out, and the excess either saved or rejected—according to its stability, commercial value, etc. To illustrate, let us revert to the problem just given, calling for 1 f ℥ of a 4% solution.

Calculation.—Since the solution is 4 per cent. strong, the solvent represents 96 per cent.; and if we take 4 parts by weight of constituent as often as we have 96 parts by weight of solvent, our finished product will contain 4 parts in 100 parts, i. e., will be exactly 4 per cent. strong.

Accordingly, 96% : 4% :: 454.6 gr.. (wt. 1 f℥ water) : x

x = 18.94 gr.

Thus by measuring out 1 f ℥ of water, and dissolving in it 18.94 gr. of constituent, we get a trifle (about 9 ♏) over 1 f ℥ of solution, exactly 4% strong.

The superiority of this method over that of making a certain weight of solution (say 500 gr.) lies in the fact that measuring is less tedious than weighing.

Problem.—A physician orders 120 c.c. of 2% solution of mercuric chloride. How can the order be filled?

Calculation.—Let 120 c.c. represent 98%. Since 120 c.c. of water weigh 120 Gm., we have—

98% : 2% :: 120 Gm. : x (2.449 Gm.)

Accordingly we dissolve 2.449 Gm. in 120 c.c. If precisely 120 c.c. of product is to be dispensed, this volume may be measured out and the excess, which represent no commercial value, may be rejected.

Note.—Percentage calculations of constituent are always based upon quantity of solution, if this is ascertainable in weight. So generally the known percentage will be 100%. But if the weight of solution (as in these problems) is an unknown, and indeterminable quantity, the calculation is based upon weight of solvent. As the entire solution = 100%, the solvent = 100% — % of active constituent. The student should therefore have no difficulty in deciding when to use 100%, and when to use a lesser %, as the basis for his calculations.

Problems.

How much solvent, and how much constituents should be used to fill the following orders:

53. 20 c.c. of 5% solution of apomorphine hydrochlor.

54. 60 c.c. of 6% solution of cocaine hydrochloride.

55. 1 L. of 10% solution of camphor in cotton seed oil, the latter having a sp. gr. of .92. Ans. 102.22 Gm.

56. 2 f ℥ 5% solution of iodine in alcohol, sp. gr. of latter, .81.

Solution.— 2 f ℥ = 2 × 454.6 gr. × .81 = 736.4 gr.

95% : 5% :: 736.4 gr. : (x) 38.7 gr.

Accordingly 38.7 gr. of iodine are dissolved in 2 f ℥ of alcohol.

57. 2 f ʒ of 4% solution of homatropine. Ans. 4¾ gr. of homatropine and 2 f ʒ of water.

58. 1 f ℥ of 20% solution of tannic acid in glycerin, sp. gr. of latter, 1.25. Ans. 142.38 gr. of tannic acid and 1 f ℥ of glycerin.

Weight to Volume Solutions.

Percentage solutions, as has been stated, are constructed on the scale of 100 weight-units. As liquid medicines are administered by volume, both per mouth and hypodermically, the dose calculations become simplified if the strength of the liquid is expressed, not in per cent., but in Gm. in 100 c.c., or in gr. in 100 ♏. The strength of most galenical preparations is expressed in this way. And most physicians would prefer to have hypodermic solutions constructed on this plan, so that by simple division the volume containing the desired dose of constituent may be calculated.

In case of metric units weight to volume solutions differ from the corresponding percentage solutions only as the sp. gr. of the solution differs from 1.000. But in case of apothecaries' units there is a further difference, due to the fact that 1 ♏ of water weighs less than 1 gr., namely about .95 gr.

In some localities much confusion has resulted from the misapplication of the conventional percentage symbol (%), this being used to express the strength of weight to volume solutions. In other words, some physicians use the % symbol, expecting the pharmacist to give it a special interpretation.

To avoid the resulting confusion the writer suggests that a new symbol, $^{w}/_{v}$, be adopted for weight to volume solutions. In case of metric prescriptions the *w* would stand for Gm., and the *v* for 100 c.c.; while in case of apothecaries' units *w* would mean gr., and *v*, 100 ♏. A 4 gr. to 100 ♏ solution would accordingly be 4 $^{w}/_{v}$, and nothing would be left to guess-work.

Problems.

60. How many gr. of atropine are required to make 1 f ℥ of a 4 $^{w}/_{v}$ solution?

Then 100 ♏ : 480 ♏ :: 4 gr. : x (19.2 gr.)*

Or: If 100 ♏ of solution contain 4 gr. of constituent, [4 gr. ÷ 100 =] .04 gr. is the amount of constituent in each ♏; and .04 gr. ×480 = 19.2 gr., the amount in 480 ♏.

Problems.

61. How many gr. of cocaine hydrochloride are required to make 4 f ʒ of a 6 $^{w}/_{v}$ solution? Ans. 14.4 gr.

62. How many f ℥ of a 4 $^{w}/_{v}$ solution could be made from 1 oz. of cocaine hydrochloride? Ans. 22 f ℥ 6 f ʒ 17 ♏.

63. What would be the $^{w}/_{v}$ strength of a solution of boric acid made by dissolving 1 oz. of the latter in enough water to make 2 pints of solution? Ans. 2.84 $^{w}/_{v}$

Other Methods for Expression of Strength of Solutions.

To avoid fractions, the strength of very dilute solutions is sometimes expressed in parts in 1000, in 2000, 5000, or even in 10000.

The solution of mercuric chloride, used as an antiseptic by surgeons, offers a case in point. As such solutions are generally for external use, the parts referred to are parts by weight.

But the sp. gr. of these very dilute solutions is so nearly 1.000, that 1 c.c. may be considered as equivalent to 1 Gm. in all cases, and 1 f ℥ as equivalent to 454.6 gr.

Problems.

64. How many gr. of mercuric chloride are required to make 1 lb. of a 1 in 1000 solution?

*In $^{w}/_{v}$ solutions c. c. of solution are proportional to Gm. of constituent; and of solution to gr. of constituent.

65. How many Gm. are required to make 2 L. of a 1 in 3000 solution?

66. How many gr. are required to make 1 pint of a 1 in 1000 solution? Ans. 7.27 gr.

67. How many gr. of mercuric chloride are required to make 2 f ℥ of a solution, 1 f ʒ of which diluted to ½ pint would make a 1 gr. to 2000 ♏ solution?

Solution.—Since ½ pint = 64 f ʒ, the solution should be 64 times as strong as a 1 gr. in 2000 ♏ solution, that is, it should be a 64 gr. in 2000 ♏ solution.

Then— 2000 ♏ : 960 ♏ :: 64 gr. : (x) 30.72 gr.

68. How many Gm. of mercuric chloride should be weighed out to make 120 c.c. of a solution 25 c.c. of which diluted to a L. would make a 1 Gm. in 3000 c.c. solution? Ans. 1.6 Gm.

CHAPTER VII.

CONCENTRATION AND DILUTION.

If 100 Gm. of a 10% salt solution is diluted to 200 Gm., that is, to double its original weight, the percentage of salt will thereby be reduced to 5%, that is, to one-half the original percentage. If the solution is diluted to four times its original weight, the percentage strength falls to one-fourth of the original percentage strength. If on the other hand the 10% salt solution is concentrated from 100 Gm. to 50 Gm. [the solvent being evaporated off without effecting loss of salt], the percentage strength is thereby doubled—becomes 20%. Thus it is seen that with the *amount* of constituent remaining unchanged, the percentage strength decreases in the same ratio in which the quantity of solution is increased, and increases in the same ratio in which the quantity of solution is decreased.

As quantity of solution and percentage strength change in the same ratio, these two values are proportional to each other; but as the change is in opposite directions, they are said to be *inversely* proportional. *However, the general rules for stating proportions, as given on page 69 are applicable to inverse proportions as well as to direct proportions.*

With the amount of constituent (C) remaining constant, the following factors come into consideration in concentration and dilution problems:

1. Initial amount of solution (or mixture, or preparation).

2. Amount after dilution or concentration.

3. Initial percentage strength of solution (or mixture, or preparation).

4. Percentage strength after dilution or concentration.

If any three of these factors are given, the fourth may be found by proportion.

If amount of diluent (to be added) is required, this is found by subtracting the initial amount of solution (or mixture, or preparation) from the amount after dilution.

N. B.—If the diluent carries active constituent, as when a stronger opium is diluted with a weaker opium, these rules do not apply. For such problems see Chapter VIII.

Since percentage is commonly weight percentage, the amounts must be in weight except when the percentage is expressly stated to be volume percentage, in which cases the amounts must be in volume.

Problems.

1. What is the % strength of a salt solution obtained by diluting 10 lb. of a 10% solution to 14 lb.?

Solution.—Percentage is asked for. Hence—

: :: 10% : x

After dilution the strength will be less than 10%. Hence the smaller of the remaining terms is the second, and the larger the first:

14 lb. : 10 lb. :: 10% : (x) $7\frac{1}{7}$%

2. What is the % strength of a salt solution obtained by evaporating 10 lb. of a 10% solution to 8 lb.?

Solution.—Percentage is asked for. Hence—

: :: 10% : x

After concentration the strength will be over 10%. Hence—

8 lb. : 10 lb. :: 10% : (x) $12\frac{1}{2}$%.

3. To what weight must 500 Gm. of 10% salt solution be evaporated in order to make a 16% solution?

Solution.—Weight is asked for; and after concentration the solution will weigh less than 500 Gm. Hence—

16% : 10% :: 500 Gm. : (x) 312.5 Gm.

4. How many Gm. of 10% nitric acid (the diluted nitric acid of the U. S. P.) can be made from 300 Gm. of nitric acid containing 68% of abs. acid? Ans. 2040 Gm.

5. How many lb. of acetic acid, 32% strong, are required to make 10 lb. of diluted acetic acid, which contains 6% of abs. acid? Ans. $1\frac{7}{8}$ lb.

6. What is the % strength of ammonia water obtained

by diluting 500 Gm. of stronger ammonia water, containing 28% of ammonia, to 1800 Gm.? Ans. $7\frac{7}{9}\%$.

7. In order to bring a certain extract of opium to the official morphine strength (20%) 1 lb. 4 oz. had to be evaporated to 14 oz. What was the morphine strength of the extract prior to the evaporation? Ans. 14%.

8. To what weight must 1 Kg. of alcohol, 91%, be diluted to make alcohol of 41% strength?*

9. How many Gm. of sulphuric acid, 70%, can be made from 4 lb. of acid of 92.5% strength?

N. B.—The two terms of a couplet must be in the same unit.

10. How many lb. of hydrochloric acid, 31.9%, are required to make 5 Kg. of 10% hydrochloric acid?

11. How many gallons of alcohol, 94% by vol., are required to make 25 L. of alcohol which is 50% strong by vol.? Ans. 3.512 gal.

12. To what weight must 600 c.c. of solution of sodium hydroxide (sp. gr., 1.437; strength, 40%) be diluted in order to make a 5% solution? Ans. 6897.6 Gm.

N. B.—Amount must be in weight for proportion.

13. What is the % strength of a diluted hydrochloric acid obtained by diluting 1 L. of hydrochloric acid (sp. gr., 1.158; strength, 31.9%) to 5 lb.? Ans. 16.3%.

14. Diluted hydrocyanic acid should contain 2% of abs. acid. To how many Gm. must 1 lb. 5 oz. 200 gr. of a 2.35% acid be diluted in order to reduce it to official strength i. e., to 2%?

15. To how many f ℥ must 500 c.c. of alcohol (sp. gr., .82; strength, 91%) be diluted in order to make 58% alcohol having a sp. gr. of .9? (See next page.)

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* Some text books give this rule for diluting alcohol:

Designate the weight-percentage of the stronger alcohol by *W*, and the desired strength by *w*.

Rule.—Mix *w* parts by weight of the stronger alcohol with water to make *W* parts by weight of the product.

To anyone familiar with the general directions for stating proportions, this rule is superfluous.

Suggestion.—Convert 500 c.c. to Gm.; find weight of dilution by proportion. Answer is in Gm. Convert this to c.c.; then to f ℥. Ans. 24.17 f ℥.

16. A certain lump of opium on assaying is found to contain 9% of morphine, and 22% of moisture. What will be the morphine strength of the opium after drying [to make powdered opium]?

Solution.—If the opium contains 22 per cent. of moisture, 100 parts will make 78 parts of the dried opium. Since no morphine is lost in the drying, the percentage strength will be higher, i. e., the answer will be greater than 9 per cent. Hence—

78 parts : 100 parts :: 9% : (x) 11.53%

17. The official extract of nux vomica is a powdered extract, and is standardized to contain 5% of strychnine. On evaporating the natural extract to dryness, it usually yields a product containing more than 5% of strychnine. The diluent used is milk sugar; and to insure its thorough incorporation, it is to be added while the extract is still of the consistency of a syrup. To calculate at this point the amount of milk sugar required, it is necessary to know the strychnine strength of the syrupy extract, and also the percentage of moisture present.

Problem.—The syrupy extract of nux vomica is found to contain 4.5% of strychnine and 20% of moisture. How much milk sugar must be added to 600 Gm. of the extract in order to yield a product which after drying will contain 5% of strychnine?

Solution.—(1). If the moisture amounts to 20 %, the yield of dry extract is 80% of 600 Gm.

100%	:	80%	::	600 Gm.	:	(x) 480 Gm.
% of syr. ext.		% of dry ext.		wt. of syr. ext.		wt. of dry ext.

(2). The strength of the dry extract is greater than 4.5%. Hence—

480 Gm. : 600 Gm. : 4.5 : (x) 5.625

(3) If the strength of this dry extract is to be lowered from 5.625 per cent. to 5 per cent., the extract must be diluted to—

5% : 5.625% :: 480 Gm. : (x) 540 Gm.

(4). To dilute the extract from 480 Gm. to 540 Gm., [540 Gm. — 480 Gm. =] 60 Gm. of milk sugar must be added.

The four steps of the process are:

(1). Finding the amount of dry extract the syrupy extract will yield.

(2.) Finding the % strength of the dry extract.

(3.) Finding the weight to which the dry extract would require dilution to reduce the strength to the required strength.

(4.) Finding by difference the amount of diluent to be added.

18. A certain lot of syrupy extract contains 12% of alkaloids and 46% of moisture. How much milk sugar must be added to 5 lb. 6 oz. to yield a product containing 15% of alkaloids after drying? Ans. 22.35 oz.

19. A certain lump of opium contains 28 % of moisture, and 8% of morphine. (a.) How much morphine could be obtained from 500 Gm. of dried opium prepared from this lump? b.) How much milk sugar would be required to reduce 200 Gm. of the dried opium to a morphine strength of 10%? Ans. (a.) 55.55 Gm.; (b,) 22.22 Gm.

20. A certain fluid extract of scopola contains 20% of extractive, i. e., solid matter, and assays .5% of mydriatic alkaloids. How much milk sugar must be added to the residue obtained from 1 Kilo. of the fluid extract, in order to yield a solid extract assaying 2% of alkaloids? Ans. 50 Gm.

21. To make 100 c.c. of paregoric of the official strength, 4 Gm. of opium containing not less than 10% of morphine, must be used. If the opium contains only 9% of morphine, how much should be used for each 100 c.c. of paregoric?

22. A Liter of a certain tincture is to contain 20 Gm. of drug, the standard alkaloid-strength of which is 1.5%. If the tincture were to be made from an extract (of the drug) of the alkaloid-content of 12%, how much of this extract should be used for each Liter of tincture?

CHAPTER VIII.

ALLIGATION.*

Alligation Medial.

COMPUTING THE PERCENTAGE STRENGTH OF A MIXTURE, OR SOLUTION, WHEN THE AMOUNTS AND THE PERCENTAGE STRENGTHS OF THE SEVERAL INGREDIENTS ARE GIVEN.

Problem.—A wholesale druggist mixes 5 lb. of opium containing 9% of morphine, 3 lb. of opium containing 6% of morphine, and 10 lb. of opium containing 12%. What is the morphine strength of the mixture?

Solution.— 5 lb. of 9 per cent. opium contain as much morphine as [5 × 9 =] 45 lb. of 1 per cent. opium would contain.

3 lb. of 6 per cent. opium contain as much morphine as [3 × 6 =] 18 lb. of 1 per cent. opium.

10 lb. of 12 per cent. opium contain as much morphine as [10 × 12 =] 120 lb. of 1 per cent. opium.

Then the 18 lb. of product [5 lb. + 3 lb. + 10 lb.] contain as much morphine as 183 lb. [45 lb. + 18 lb. + 120 lb.] of 1 per cent. opium would contain. And the morphine strength of the product must be as many times 1 per cent. as 18 lb. is contained in 183 lb. 183 ÷ 18 = 10.16. Hence the morphine strength of the product is 10.16 per cent.

This operation may be made the basis of the following rule:

1. Multiply the amounts of the several ingredients (all of which must be expressed in the same unit) by their percentage strengths.

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*From the Latin *alligare*, to bind:—referring to the linking together of values in alligation alternate, as shown on page 90.

$$5[\text{lb.}] \times 9[\%] = 45. [\% \text{ units}].$$
$$3[\text{lb.}] \times 6[\%] = 18. [\% \text{ units}].$$
$$10[\text{lb.}] \times 12[\%] = 120. [\% \text{ units}].$$

2. Add the products.

$$45 + 18 + 120 = 183 [\% \text{ units}].$$

3. Add also the amounts.

$$5 + 3 + 10 = 18[\text{lb.}]$$

4. Divide the sum of the products by the sum of the amounts.

$$183 \div 18 = 10.16.$$

The quotient is the percentage strength of the mixture.

Note.—In case the strengths are given in volume-percentage, the amounts must be in volume; if in weight-percentage, the amounts must be in weight, as in the example.

Problems.

1. A drug house receives two shipments of cinchona. The first, consisting of 500 lb., contains on an average 3.3% of quinine. The second, consisting of 300 lb., contains 2.1% of quinine. What is the quinine strength of the product obtained by mixing the two lots? Ans. 2.85%.

2. A druggist finds in his laboratory the following lots of diluted alcohol: 1500 c.c., 60% by vol. strong, 400 c.c., 40% by vol. strong, 1 pint, 50% by vol. strong. What is the strength of the product obtained by mixing the three lots? Ans. 54.63%.

Computing the Specific Gravity of a Mixture When the Amounts and the Specific Gravities of the Ingredients are Given.

The principles of alligation medial apply also to specific gravities. But it is required that the amounts be in volume,

and not in weight; for specific gravity expresses the weight of a unit of volume — not of a unit of weight.*

3. What would be the sp. gr. of the product obtained by mixing 3000 c. c. of benzin and 1200 c.c. of naphtha, the former having a sp. gr. of .67, and the latter of .718?

Solution— 3000 c.c. × .67 [sp. gr.] = 2010 Gm.
1200 c.c × .718 [sp. gr.] = 861.6 Gm.

4200 c. c 2871.6 Gm.

2871.6 ÷ 4200 = .683 (sp. gr. of mixture).

4. What would be the sp. gr. of a mixture of 2 f ℥ of bromoform, sp. gr., 2.9, and 8 f ℥ of chloroform, sp. gr., 1.48? Ans. 1.764.

5. What would be the sp. gr. of a mixture of 150 Gm. of ether, sp. gr., .716 and 200 Gm. of chloroform, sp. gr., 1.48?

Suggestion.—Reduce Gm. to c.c.; then proceed by alligation medial. Ans. 1.015.

6. What would be the sp. gr. of a mixture of 1 pint of alcohol, sp. gr., .81, and 1 lb. of ether, sp. gr., .716? Ans. .756.

---

*A cubic centimeter of water weighs 1 Gramme. A c.c. of a liquid having a sp. gr. of 3, weighs 3 Gm. On mixing 1 c.c. of water, sp. gr. 1, with 1 c.c. of the liquid, sp. gr., 3, we get 2 c.c. of product, weighing 1 + 3 = 4 Gm. If 2 c.c. weigh 4 Gm., 1 c.c. will weigh 4 Gm. ÷ 2 = 2 Gm. Then the sp. gr. of the product must be 2, which by laboratory experiment can be proven to be correct.

But suppose that 1 Gm. of water and 1 Gm. of the liquid are mixed. What will be the sp. gr. of the product?

Misapplying the rule to weights we obtain the same answer as before—namely, sp. gr., 2. This cannot be correct if the answer to the first problem is correct; for the proportion of 1 Gm. of water to 1 Gm. of the liquid is the same as 1 c.c. of water to ⅓ c.c. of the liquid, while in the first problem we have 1 c.c. of each. But on reducing the weights to volumes, and then applying the rule, we obtain for an answer the sp. gr. of 1.5.

1 c.c. × 1 [sp. gr.] = 1 Gm.
⅓ c.c. × 3 [sp. gr.] = 1 Gm. Then 2 ÷ 1 ⅓ = 1.5. [sp. gr. of mixt.]

1 ⅓ c.c. 2 Gm.

This by laboratory experiment can be proven to be correct. [In practice it is difficult to find two liquids of which one has a sp. gr. just three times that of the other. Even numbers were used in the example for sake of brevity and simplicity. For the laboratory experiment any two liquids which are miscible, and differ considerably in sp. gr., may be used.]

Alligation Alternate.

To Find the Proportion in Which Ingredients of Known Strength Must be Mixed to make a Mixture of Required Strength.

Problem.—In what proportion must opium 10% strong and opium 14% strong be mixed to make opium 13% strong?*

Solution.—The strength of the stronger opium is 1% too high; that of the weaker opium is 3% too low. Since the difference between the strength of the stronger opium and the required strength is just ⅓ as great as the difference between the strength of the weaker opium and the required strength, three parts of the stronger opium must be taken to one part of the weaker. In other words, the excess in strength of three parts of the stronger opium will just balance the deficiency of one part of the weaker opium.

Problem.—In what proportion must opium 10% strong and opium 15% strong be mixed to make opium 13% strong?

Solution.—The weaker opium is 3% too weak; the stronger is 2% too strong. Then the excess in strength of 3 parts of the stronger will just balance the deficiency of 2 parts of the weaker. For 2 [parts] × 3 [%] = 6; and 3 [parts] × 2 [%] = 6.

[The same principle applies in alligation alternate as is applied in writing chemical formulae.—The formula for zinc phosphide is Zn_3 P_2. Now zinc has 2 valencies, and phosphorus has 3. Hence 3 atoms of bivalent zinc have as many valencies (6) as 2 atoms of trivalent phosphorus. In like manner 3 parts of the opium which is 2% too strong will fortify to the required strength 2 parts of the opium which is 3% too weak.]

General Rule.

Per cent. of *stronger* ingredient minus desired per cent. equals parts of *weaker* ingredient.

Per cent. desired minus per cent. of *weaker* ingredient equals parts of *stronger* ingredient.

*Official opium contains from 12 to 12.5% of morphine.

In case there are more than two ingredients, their percentage strengths must be paired off so that the difference between each percentage strength and the required percentage strength is just compensated for by the proper number of parts of the opposite kind.

Problem.—In what proportion must alcohol, 20% strong, alcohol, 40% strong, alcohol, 65% strong, and alcohol, 90% strong, be mixed to make alcohol which is 50% strong?

Proceed as follows:

1. Write the percentages in a column [preferably in numerical order]. Place a brace [{] in front of the column, and in front of the brace write the required percentage. Thus—

$$50\,\% \left\{ \begin{array}{l} 20\% \\ 40\% \\ 65\% \\ 90\% \end{array} \right.$$

2. Connect with a line each percentage which is greater than the required percentage with one that is less than the required percentage; and each one that is less with one that is greater than the required percentage. Thus—

$$50\% \left\{ \begin{array}{l} 20\% \\ 40\% \\ 65\% \\ 90\% \end{array} \right. \quad \text{or} \quad 50\% \left\{ \begin{array}{l} 20\% \\ 40\% \\ 65\% \\ 90\% \end{array} \right.$$

3. Write the difference between the first percentage and the required percentage opposite the percentage connected with the first percentage by a line. Proceed in this manner with all the percentages, in each case writing the difference not opposite the percentage compared, but opposite the percentage at the other end of the line. Thus—

$$50\% \left\{ \begin{array}{l} 20\% = 40 \\ 40\% = 15 \\ 65\% = 10 \\ 90\% = 30 \end{array} \right.$$

The difference between 20% and 50% being 30%, 30 is placed opposite 90%.

The difference between 40% and 50% being 10%, 10 is placed opposite the 65%.

The difference between 65% and 50% being 15, 15 is placed opposite the 40%. The difference between 90% and 50% being 40, 40 is placed opposite the 20%.

The other answer is—

$$50\% \left\{ \begin{array}{l} 20 = 15 \\ 40 = 40 \\ 65 = 30 \\ 90 = 10 \end{array} \right.$$

The differences denote the number of parts which should be used of the several ingredients to make a mixture of the desired strength. In case of weight-percentage the proportionate parts are parts by weight; and in case of volume percentage they are parts by volume.

Proof.

For first answer.

By Alligation Medial.

40 [parts] × 20 [%] = 800 [% units]
15 [parts] × 40 [%] = 600 [% units]
10 [parts] × 65 [%] = 650 [% units]
30 [parts] × 90 [%] = 2700 [% units]

95 [parts] contain 4750 [% units]

Then— 4750 ÷ 95 = 50%.

Remarks.—When there are more than three ingredients, a number of correct answers are possible, because the percentages may be paired off in different ways. And even in case of but three ingredients—when but one answer is obtainable by alligation—the ingredients may be mixed in an indefinite number of proportions. So the answer obtained by alligation, in case of three ingredients, is not the only correct answer: it is *a* correct answer. And the answers obtained by alligation in case of four or more ingredients, are *not all*, but *only some*, of the correct answers.

In Case Either the Weaker or the Stronger Ingredients Exceed in Number.

Problem.—A wholesale druggist has five lots of opium—8%, 10%, 11%, 14% and 15% morphine strength respectively. In what proportion *may* these be mixed in order to make a product of 12% morphine strength?

Remember that in no case can a weaker % be connected with a weaker, or a stronger with a stronger.

Proceed as in the preceding example, except that one of the percentages must be connected with *two* others:

$$12\% \left\{ \begin{array}{l} 8\% = 3 \\ 10\% = 2 \\ 11\% = 2 \\ 14\% = 2 + 1 \\ 15\% = 4 \end{array} \right.$$

As the 14% is connected with *two* other percentages, the difference between 14% and the required percentage must be placed opposite *both* the percentages thus connected; i. e., opposite the 10%, and the 11%. And the difference between 10% and 12%, and the difference between the 11% and 12%, are both to be placed opposite the 14%.

Question.—How many correct answers to this problem are obtainable by alligation alternate?

Problems.

7. In what proportion should alcohol, 91% strong, be mixed with alcohol, 48% strong, to make alcohol 70% strong? Ans. 22 parts of 91% and 21 parts of 48%.

8. In what proportion must cinchona containing 11% of total alkaloid, cinchona containing 8%, and cinchona containing 4%, be mixed to make a product containing 5% of alkaloids? Ans. 1 part of 11%, 1 part of 8%, and 9 parts of 4%.

9. In what proportion should jalap containing 5% resin, jalap containing 7%, jalap containing 4%, and jalap

containing 3%, be mixed to make a product containing 6%?

In case of fractional parts.

10. In what proportion must coca .8% strong be mixed with coca .38% strong to make a product .5% strong?

Solution.—

$$.50 \text{ per cent.} \begin{cases} .38 \text{ per cent.} = .30 \text{ parts, which} \times 100 = 30 \text{ parts.} \\ .80 \text{ per cent.} = .12 \text{ parts, which} \times 100 = 12 \text{ parts.} \end{cases}$$

Note.—As fractions are cumbersome, eliminate them by multiplication. In this case multiply by 100.

11. In what proportion should belladonna .38%, belladonna, .18%, and belladonna, .30%, be mixed to make a product .35% strong? Ans. 22 parts of .38%, 3 parts of each of the others.

In Case Active Constituents, or Diluents, or Both are Ingredients in the Mixture.

Problem.—In what proportion must chloroform be added to a 20% solution of chloroform to increase the strength of the latter to 35%?

Solution.—The chloroform figures in the calculation as a 100 per cent. solution, thus—

$$35 \text{ per cent.} \begin{cases} 20 \text{ per cent.} = 65 \text{ parts} \qquad = 13 \text{ parts.} \\ \qquad \text{or by cancellation} \\ 100 \text{ per cent.} = 15 \text{ parts} \qquad = 3 \text{ parts.} \end{cases}$$

Then 65 parts of solution require 15 parts of chloroform. Or, reducing the ratio to its simplest expression by cancellation— 13 parts of solution require 3 parts of chloroform.

Problem—In what proportion should alcohol, 91% strong, alcohol, 48% strong, and water be mixed to make a product 35% strong?

Solution.—The water may be considered as an alcohol of zero percentage. Then—

$$35\% \begin{cases} 0\% \text{ (water)} = 13 + 56 = 69 \text{ parts.} \\ 48\% = 35 \text{ parts.} \\ 91\% = 35 \text{ parts.} \end{cases}$$

Problems.

12. In what proportion must potassium iodide be added to a potassium iodide solution 15% strong in order to increase its strength to 25%? Ans. 2 parts of potass. iodide to 15 parts of 15% solution.

13. In what proportion should opium 10% strong, opium 15% strong, and milk sugar be mixed to make a product 13% strong? Ans. 2 parts of 10%, 16 parts of 15%, and 2 parts of milk sugar.

14. In what proportion should absolute acetic acid, acetic acid 36% strong, and water be mixed to make acetic acid 60% strong?

To Find the Proportion in Which Ingredients of Given Specific Gravities Must be Mixed to Make a Mixture of Given Specific Gravity.

Alligation alternate is applicable to volumes of liquids and their specific gravities, provided a change in volume, due to chemical action, does not take place.*

Specific gravities of mixtures of alcohol and water cannot be calculated. See U. S. P. alcohol table.

Problem.—In what proportion by volume must petrolatum, sp. gr., .82, be mixed with petrolatum, sp. gr., .85, to make a product having the sp. gr. of .83?

Solution.—

$$.83 \begin{cases} .85 = .01 \times 100 = 1. \text{ parts.} \\ .82 = .02 \times 100 = 2. \text{ parts.} \end{cases}$$

Eliminating the fractions, the answer is, 2 parts by

*The parts calculated from specific gravities are in every case parts by volume. See page 97.

volume of the lighter to 1 part by volume of the heavier patrolatum.

Problems.

15. A mixture of ether (.716) and absolute alcohol (.79) has a sp. gr. of .75. What proportion by volume of ether does it contain? Ans. 40 vol. of ether to 34 vol. of abs. alcohol.

16. In what proportion by volume should glycerin, sp. gr., 1.25, alcohol, sp. gr., .82, be mixed to make a product having a sp. gr. of .95? Ans. Glycerin 13 p., alcohol, 30 p.

17. In stock we have two solutions of soda, the sp. gr. of one being 1.06, that of the other, 1.5. In what proportion must these be mixed to yield a product of the sp. gr. of 1.225? Ans. 275 vol. of 1.06 to 165 vol. 1.5, which reduced to simplest expression gives 5 vol. to 3 vol.

In Case the Quantity of One of the Ingredients is Specified, and the Quantity of the Other Ingredients is to be Calculated.

Problem.—How much scammony having a resin-content of 82% must be mixed with 5 lb. of scammony having a resin-content of 93%, to make a product having a resin-content of 90%?

Solution.—By alligation alternate we determine in what proportion the two qualities must be mixed:

$$90 \text{ per cent.} \begin{cases} 82 \text{ per cent.} = 3 \text{ parts.} \\ 93 \text{ per cent.} = 8 \text{ parts.} \end{cases}$$

From the proportionate parts we calculate the quantities by proportion.

The three known terms are—3 parts, 8 parts, and 5 lb. Since quantity (weight) is asked for, 5 lb. must be the third term. The quantity of the weaker scammony is asked for; and as this is to be used in the proportion of 3 parts to 8 of the other, 3 being less than 8, the answer is to be smaller than 5 lb. Hence—

$$8 \text{ parts} : 3 \text{ parts} :: 5 \text{ lb.} : (x)\ 1\tfrac{7}{8} \text{ lb.} = 1 \text{ lb. } 14 \text{ oz.}$$

In order that confusion may be avoided it is well to place the given quantity opposite the proportionate parts

which are to be taken of the ingredient for which the quantity is given, and to place an interrogation point to indicate the quantities sought; thus—

$$90\% \left\{ \begin{array}{l} 82\% = 3 \text{ parts} = ? \\ 93\% = 8 \text{ parts} = 5 \text{ lb.} \end{array} \right.$$

The known terms may now be located without difficulty; and whether the answer should be greater or smaller than the given quantity—the third term—may be seen by inspection. The interrogation point follows "3 parts" in the example; a given quantity follows "8 parts." Since 3 is smaller than 8, the answer must be smaller than 5 lb.—the given quantity.

Problem—How much alcohol, 45% strong, how much 60% strong, and how much water, should be mixed with 500 Gm. of alcohol, 90% strong, in order that the product may have a strength of 50%?

Solution.—

$$50\% \left\{ \begin{array}{lll} 0\% & \text{(water)} & = 40 \text{ parts} = ? \\ 45\% & & = 10 \text{ parts} = ? \\ 60\% & & = 5 \text{ parts} = ? \\ 90\% & & = 50 \text{ parts} = 500 \text{ Gm} \end{array} \right.$$

Then by proportion*:

50 parts : 40 parts : : 500 Gm. : x (400 Gm.)
50 parts : 10 parts : : 500 Gm. : x (100 Gm.)
50 parts : 5 parts : : 500 Gm. : x (50 Gm.)

Proof.

$$\begin{array}{rrcl} & 400 \text{ Gm.} \times 0\% & = & 0\% \text{ unit} \\ & 100 \text{ Gm.} \times 45\% & = & 4500\% \text{ units} \\ & 50 \text{ Gm.} \times 60\% & = & 3000\% \text{ units} \\ \text{and} & 500 \text{ Gm.} \times 90\% & = & 45000\% \text{ units} \\ \hline & 1050 \text{ Gm.} & = & 52500\% \text{ units} \end{array}$$

$$52500 \div 1050 = 50 \ [\%].$$

---

* The general proportion is—
parts of ingredient, quantity of which is given : parts of ingredient, quantity of which is sought : : quantity given : x
x = quantity sought.

Problems.

18. How many Gm. of nitric acid, 68% strong, must be added to 500 Gm. of acid, 10% strong, to make a product 50% strong? Ans. 1111.111 Gm.

19. How many Gm. of sulphuric acid, 90% strong, must be added to 1 L. of water to make an acid 10% strong?

20. How many c.c. of water should be added to 1 L. of a solution of soda, sp. gr., 1.4, in order to make a solution of the sp. gr. of 1.2?

21. How many f℥ of ammonia water, sp. gr., .96, must be added to 8 f℥ of ammonia water, sp. gr., .92, to make a product having a sp. gr. of .95? Ans. 24. f℥.

22. How many c.c. of ether, sp. gr., .716, must be added to 1 L. of chloroform, sp. gr., 1.48, to yield a product of the sp. gr. of 1.25? Ans. 430.7 c.c.

In Case the Quantity is Specified for Several Ingredients.

Problem.—We have 5 lb. of acetic acid, 28% strong, 3 lb. of acetic acid, 20% strong, and 1 lb., 10% strong. How much glacial acetic acid, 99% strong, should be added to a mixture of these in order that the product may have the strength of 36%?

Solution.—

$$
\begin{array}{lcl}
5 \text{ lb.} \times 28\,\% & = & 140\,\% \text{ units} \\
3 \text{ lb.} \times 20\,\% & = & 60\,\% \text{ units.} \\
1 \text{ lb.} \times 10\,\% & = & 10\,\% \text{ units.} \\
\hline
9 \text{ lb.} & = & 210\% \text{ units} \\
\end{array}
$$

$$210 \div 9 = 23\ {}^{1}\%$$

A mixture of the given quantities would be 23⅓% strong, and the weight of the mixtures would be 9 lb. The problem has now been simplified to — How much acetic acid 99% strong must be added to 9 lb. of acid 23⅓% strong, to make a product 36% strong?

$$36\% \begin{cases} 23\tfrac{1}{3}\% = 63 \text{ parts} = 9 \text{ lb.} \\ 99\ \% = 12\tfrac{2}{3} \text{ parts} = ? \end{cases}$$

Then— 63 parts : $12\frac{2}{3}$ parts : : 9 lb. : (x) $1\frac{17}{21}$ lb = 1 lb. 12 oz. 417 gr.

Problems.

23. A druggist has 400 Gm. of opium, 10% strong, 350 Gm., 12% strong. How much opium, 16% strong, should he add to a mixture of the 10% and the 12% opium to make a product 13% strong? Ans. 516.66 Gm.

24. How much ammonia water, 28%, should be added to a mixture of 5 lb. of ammonia water, 10%, and 300 Gm., 8%, to make a product 15% strong?

25. In a laboratory there are three lots of solution of potassium iodide as follows:—400 Gm. of 5%, 200 Gm. of 12%, and 300 Gm. of 15%. How much potassium iodide must be dissolved in a mixture of the three lots to make a product 25% strong? Ans. 181.33 Gm.

In Case the Quantity of Product Wanted is Specified, and Quantity of Each of the Ingredients is to be Calculated.

Problem.—How much cinchona, quinine-strength, 3.9% and how much cinchona, 2.4%, must be used to make 10 lb. of a product having a quinine-strength of 3%?

$$\textbf{Solution.—}3\% \begin{cases} 3.9\% = .6 \times 10 = 6 \text{ parts} = ? \\ 2.4\% = .9 \times 10 = \underline{9} \text{ parts} = ? \end{cases}$$
$$\overline{15} \text{ parts} = 10 \text{ lb.}$$

If 6 parts and 9 parts are mixed, the product will be 15 parts. Then to make 15 parts of the product 9 parts of the cinchona, 2.4%, must be used; and from these 9 parts the quantity for 10 lb. may be found by proportion, weights being proportional to proportionate parts.

Thus— 15 parts : 9 parts :: 10 lb. : (x) 6 lb.*

In like manner the quantity of the stronger cinchona may be calculated:

15 parts : 6 parts :: 10 lb. : (x) 4 lb.*

Proof.

$$\begin{array}{lcl} 6 \text{ lb.} \times 2.4\% & = & 14.4\% \text{ units.} \\ 4 \text{ lb.} \times 3.9\% & = & 15.6\% \text{ units.} \\ \hline 10 \text{ lb.} & & 30.0\% \text{ units.} \end{array}$$

$$30 \div 10 = 3\%$$

and

$$6 \text{ lb.} + 4 \text{ lb.} = 10 \text{ lb.}$$

Problems.

26. How many Gm. of colchicum, alkaloidal strength, .4%, and how many Gm. of the strength of .56%, must be used to make 20 Kgm. of product of an alkaloidal strength of .5%? Ans. 7500 Gm. of .4%, and 12500 Gm., of .56%.

27. How many gr. of mercuric chloride must be added to how many gr. of mercuric chloride solution, 2% strong, to make 500 gr. of a solution which is 5% strong?

28. 5 lb. of opium containing 14% of morphine is wanted. How much 9% opium, how much 11%, and how much 15.4% may be used to make a mixture of required weight and strength. Ans. of 9% and 11% each .648 + lb.; of 15.4 %, 3.7 + lb.

—It will be observed that the general proportion is: Sum of the parts : parts of the ingredient : : weight of the mixture : x. x = weight of the ingredient.

Observe that the sum of the proportionate parts enters into the calculation only when the quantity of the entire mixture is used as a basis for the calculation of the amounts of the ingredients. When the amount of one ingredient is calculated from the amount of another ingredient, the sum is *not* used.

In Case Quantity of Product Wanted, and also the Quantity of One or More Ingredients is Specified.

Problem.— 1000 Gm. of alcohol, 50% strong, is to be made from 100 Gm. of 80% alcohol, by the addition of 40% and 65% alcohol. How much of each of the latter two strengths should be used?

Solution.—50% $\begin{cases} 80\% = 10 \text{ parts} = 100 \text{ Gm.} \\ 40\% = 30 \text{ parts} = ? \end{cases}$

10 parts : 30 parts :: 100 Gm. : (x) = 300 Gm.

To reduce the 100 Gm. of 80% to the desired percentage 300 Gm. of 40% must be used. This will make 400 Gm. of mixture. But 1000 Gm. are wanted. 1000 Gm. — 400 Gm. = 600 Gm., which is the amount to be made by mixing 40% and 65% alcohol.

50% $\begin{cases} 40\% = 15 \text{ parts} = ? \\ 65\% = 10 \text{ parts} = ? \end{cases}$

25 parts = 600 Gm.

25 parts : 15 parts :: 600 Gm. : (x) 360 Gm. of 40%
and 25 parts : 10 parts :: 600 Gm. : (x) 240 Gm. of 65%

Proof.

100 Gm. of 80% =	8000% units.
300 Gm. of 40% =	12000% units.
360 Gm. of 40% =	14400% units.
240 Gm. of 65% =	15600% units.
1000 Gm.	50000% units.

50000 ÷ 1000 = 50 [%].

CHAPTER IX.

CHEMICAL PROBLEMS.

Problems Based on Chemical Formulas.

Molecules.—It is a generally accepted theory that matter is not infinitely divisible, but that, when division has been carried to a certain extent, particles will be obtained which cannot be divided without destroying the chemical character of the substance. These particles have been called molecules. They are inconceivably small; but how small—of what volume, and of what weight—is not known*.

Atoms.—Nevertheless, molecules are—so it is generally believed—composed of still smaller particles, which are called atoms. An atom may be defined as the smallest particle of an element known to enter into chemical *combination.*†

To show more clearly the relationship of atoms to molecules the following application of these definitions may be of service: The molecule of hydrochloric acid is a particle of that substance so small that it cannot be further divided into particles having the properties of hydrochloric acid. However, by chemical means, the particle can be divided into two dissimilar particles—hydrogen, and chlorin, each of which is different from the acid, the latter having been destroyed. The fact that such division is possible, indicates that molecules are composed of still smaller particles.

Atomic Weights.—Of the size and actual weight of atoms no more is known than of the size and weight of molecules.

However, the *relative weights* of atoms have been determined with considerable accuracy. To illustrate: the weight of an atom of sulphur is not known; but it is known

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*According to calculations based upon the kinetic theory of gases, a molecule of hydrogen weighs about .000,000,000,000,000,000,000,004 Gm. But accuracy is not claimed for this result.

†When an element exists free, its smallest particle is a molecule. The molecules of most elements appear to contain two atoms; but mercury, zinc, and cadmium each contain but one atom in a molecule; while phosphorus, and arsenic each contain four.

that an atom of sulphur weighs practically twice as much as an atom of oxygen, and that an atom of the latter element weighs about 16 times as much as an atom of hydrogen—whatever weight that is.

The standard adopted for the expression of these ratios is OXYGEN = 16, which means that an atom of oxygen is assumed to weigh 16 units, and that an atom of an element the atomic weight of which is given as 12 (carbon) weighs three-fourths as much as an atom of oxygen.

These relative weights have been worked out with great accuracy for the known elements, and are known as *atomic weights*. They are, however, ratios—not actual weights. See table, page 146.

Molecular Weights.—The molecular weight of a compound is its relative weight as compared with an atom of oxygen, the weight of the latter being taken as 16. In other words, the standard for molecular weights is the same as for atomic weights. Indeed, the molecular weight of any compound is simply the sum of the relative weights of the atoms in the molecule of that compound. Thus, the molecular weight of oxygen (O_2) is 32; the molecular weight of CO_2 is $12 + 16 + 16 = 44$.

It follows, then, a table of atomic weights being accessible, that the molecular weight of any compound may be calculated if its molecular formula is known. Also, that the percentage composition of a compound may be calculated from its molecular formula; and conversely, that the molecular formula may be calculated if the percentage composition and the molecular weight have been determined experimentally.

But the student should remember that these calculations have an ultimate basis of experimental work. For instance, the molecular weight of CO_2 can now be calculated, because the atomic weights concerned, and the vapor density, are known.

CALCULATION OF MOLECULAR FORMULA.

The following data are necessary, and are, of course, determined experimentally:

1. The molecular weight of the compound.

2. The identity of the elements in the compound, and the atomic weights of these elements.

3. The proportion in which the component elements are present. [Expressed in parts by weight, usually in percentage.]

Problem.—Suppose the molecular weight of the compound has been found to be 90; and the percentage composition as follows:—carbon, 40%, hydrogen, $6\frac{2}{3}$ %, oxygen, $53\frac{1}{3}$%. Assuming the atomic weight of hydrogen to be 1, carbon 12, and oxygen 16, what is the formula of the compound?

Process.—First calculate how many parts of each of the three elements would be present in 90 parts, 90 being the molecular weight:

$$100\% : 40\% :: 90 \text{ parts} : x \text{ (36 parts)}.$$
$$100\% : 6\tfrac{2}{3}\% :: 90 \text{ parts} : x \text{ (6 parts)}.$$
$$100\% : 53\tfrac{1}{3}\% :: 90 \text{ parts} : x \text{ (48 parts)}.$$

Then divide the parts for each of the elements by the atomic weight of that element. Thus—

Carbon, 36 parts $\div$ 12 (at. wt.) = 3.
Hydrogen, 6 parts $\div$ 1 (at. wt.) = 6.
Oxygen, 48 parts $\div$ 16 (at. wt.) = 3.
The molecular formula is $C_3H_6O_3$.

Note.—The calculation is here simplified by use of approximate atomic weights. In practice the accurate atomic weights are employed.

CALCULATION OF MOLECULAR WEIGHT FROM MOLECULAR FORMULA.

As has been stated, the molecular weight of a compound must be determined experimentally before it becomes possible to deduce the molecular formula. But when the latter

is known, the molecular weight may be calculated *from* the molecular formula; for the molecular weight is the sum of the weights of the atoms in the molecule.

For instance: The molecular weight of NaOH is the atomic weight of Na = 23, plus the atomic weight of O = 16, plus the atomic weight of H = 1.008, which gives a total of 40.008, or 40 if the approximate atomic weight of 1 is used for H.

Problem.—Calculate the molecular weight of H_2SO_4.

Solution.—

$$\begin{aligned} H_2 &= \mathit{1} \times 2 = 2 \\ S &= \mathit{32} \times 1 = 32 \\ O_4 &= \mathit{16} \times 4 = 64 \\ \text{Mol. wt. of } H_2SO_4 &= 98 \end{aligned}$$

Note.—The numbers in italics are the atomic weights.

Problem.—Calculate the molecular weight of

$Na_2CO_3.10H_2O$.

Solution.—

$$\begin{aligned} Na_2 &= \mathit{23} \times 2 = 46 \\ C &= \mathit{12} \times 1 = 12 \\ O_3 &= \mathit{16} \times 3 = 48 \\ 10\,H_2 = H_{20} &= \mathit{1} \times 20 = 20 \\ 10\,O &= \mathit{16} \times 10 = 160 \\ \text{Mol. wt. of } Na_2CO_3.10H_2O &= \overline{286} \end{aligned}$$

Problem.—Calculate the molecular weight of

$Mg(CO_3)_4.Mg(OH)_2.5H_2O$.

Solution.—Reducing the rational formula to an empirical formula gives $Mg_5C_4O_{19}H_{12}$.

$$\begin{aligned} Mg_5 &= \mathit{24.32} \times 5 = 121.60 \\ C_4 &= \mathit{12} \times 4 = 48 \\ O_{19} &= \mathit{16} \times 19 = 304 \\ H_{12} &= \mathit{1} \times 12 = 12 \\ \text{Mol. wt. of } (MgCO_3)_4.Mg(OH)_2.5H_2O &= \overline{485.60} \end{aligned}$$

Problems.

These answers were obtained by use of accurate atomic weights. The student may, however, shorten the work of figuring by using approximate atomic weights in all cases when the calculations are performed merely for practice, and not in connection with laboratory exercises.

1. Calculate the molecular weight for (a.) H_2O; (b.) $NaOH$; (c.) $HgCl_2$; (d.) $C_{10}H_8$. Ans. (d.) 128.
2. For—(a.) $FeSO_4.7H_2O$; (b.) $Fe_2(PH_2O_2)_6$; (c.) $HC_3H_5O_3$. (d.) $Al_2K_2(SO_4)_4.24H_2O$. Ans. (d.) 949.
3. For—(a.) $C_{12}H_{22}O_{11}$; (b.) $CHCl_3$. Ans. (a.) 342.
4. For—$C_{20}H_{24}N_2O_2.3H_2O$ (Quinine). Ans. 378.
5. For—$(C_{21}H_{22}N_2O_2)_2H_2SO_4.5H_2O$ (Strychnine Sulphate). Ans. 856.5.

Note.—Remember that a subscript following a symbol applies to that symbol only; that a subscript following parentheses multiplies all within the parentheses; and that a coefficient preceding a formula multiplies the entire formula. If, however, the coefficient precedes only part of a formula, only the portion which follows is affected by the coefficient. Thus in the formula $K_4Fe(CN)_63H_2O$ the subscript 4 multiplies K; the subscript 6 multiplies C and N; and the coefficient 3 multiplies H_2O.

Calculation of the Percentage Composition of a Compound from its Formula.

Problem.—Calculate the percentage composition of Fe_2O_3.

Solution.—

$$\begin{aligned} Fe_2 &= 55.8 \times 2 = 111.6 \\ O_3 &= 16 \times 3 = \underline{48} \\ \text{Mol. wt. of } Fe_2O_3 &= 159.6 \end{aligned}$$

Atomic weights, and hence also molecular weights, may be considered as *parts by weight*. It follows then that 159.6 parts of Fe_2O_3 contains 111.6 parts of Fe. From these data the percentage of Fe may be calculated by proportion in the usual manner:

The three known terms are, 159.6 parts, 111.6 parts, and 100%. The answer is to express %. Hence—

$$: \quad :: \quad 100\% \quad : \quad x$$

The answer is to be smaller than 100%, because a part must be smaller than the whole. Hence—

159.6 parts : 111.6 parts :: 100% : x

$x = 69.9\% = \%$ of Fe.

In like manner the percentage of O may be calculated:

159.6 parts : 48 parts :: 100% : x

$x = 30.07\% = \%$ of O.

Problem.—What is the percentage composition of $C_6H_{12}O_6$?

Solution.—

$$\begin{aligned} C_6 &= 12 \times 6 = 72 \\ H_{12} &= 1 \times 12 = 12 \\ O_6 &= 16 \times 6 = \underline{96} \\ & \qquad\qquad 180 \end{aligned}$$

Then—

180 parts : 72 parts :: 100% : x

$x = 40\% = \%$ of C.

180 parts : 12 parts :: 100% : x

$x = 6.6\% = \%$ of H.

180 parts : 96 parts :: 100% : x

$x = 53.3\% = \%$ of O.

Problems.

6. Calculate the percentage composition of—(a.) H_2O; (b.) H_2O_2; (c.) H_3PO_4; (d.) $C_{12}H_{22}O_{11}$; (e.) $C_{20}H_{24}N_2O_2.3H_2O$ [quinine]. Ans. (a.) 11.1 + % of H and 88.8 + % of O.

The Percentage-Content of Only One Element or Group of Elements is Required.

Problem.—What is the percentage of iron in $FeSO_4.7H_2O$?

Solution.—

$$\begin{aligned} Fe &= 55.84 \times 1 = 55.84 \\ S &= 32.7 \times 1 = 32 \\ O_4 &= 16 \times 4 = 64 \\ 7H_2 &= 1 \times 7 \times 2 = 14 \\ 7O &= 16 \times 7 = \underline{112} \\ \text{Mol. wt. of } FeSO_4.7H_2O &= 277.84 \end{aligned}$$

Then— 277.84 parts : 55.84 :: 100% : x
$x = 21\% = \%$ of Fe.

Problem.—Calculate the percentage of water of crystallization in $Na_2CO_3.10H_2O$.

Solution.—The molecular weight of $Na_2CO_3.10H_2O$ is 286.16.

The molecular weight of H_2O is 18; hence the relative weight for the ten molecules is 180.

In other words, 286.16 parts of $Na_2CO_3.10H_2O$ contain 180 parts of water.

Then—286.16 parts : 180 parts :: 100% : x (62.9%).

Problems.

7. What % of anhydrous $FeCl_3$ in $FeCl_3.6H_2O$?
8. What % of Fe in $FeCl_3.6H_2O$? Ans. 20.69%.
9. What % of C in CH_4?
10. What % of I in CHI_3 [iodoform]? Ans. 96.6 + %.
11. What % of I in C_4NHI_4 [iodol]? Ans. 89%.
12. What % of arsenic in realgar—an arsenical ore of the composition As_2S_2?
13. What % of zinc in sphalerite—a zinc ore of the composition of ZnS? Ans. 67%.
14. What % of water of crystallization in $FeSO_4.7H_2O$?
15. In making dried sodium carbonate the crystallized sodium carbonate is heated until it has lost one-half its weight. What % of water of crystallization remains in the dried carbonate?

Solution.—Mol. wt. of $Na_2CO_3.10H_2O = 286.16$.

If the weight is reduced to one-half, the molecular weight of the product must be $286.16 \div 2 = 143$. The molecular weight of anhydrous $Na_2CO_3 = 106$. Then 143 minus $106 = 37 =$ weight of water in the molecule of dried carbonate.

And 143 parts : 37 parts :: 100% : x (25.87%).

16. How many molecules of water of crystallization in the dried sodium carbonate?

Solution.—If the molecular weight is one-half that of the crystallized carbonate, there are about 37 parts of water present; for $143 - 106 = 37$. And $37 \div 18$ (mol. wt. of

$H_2O) = 2+$. So a little over two molecules are present; and the formula $Na_2CO_3.2H_2O$ is nearly correct for the dried carbonate, U. S. P., 1890.

Calculations Based on Chemical Reactions.

Atomic weights are relative weights, and for arithmetical purposes may be thought of as parts by weight. This being true of atomic weights, it must be true also for molecular weights and for multiples of molecular weights.

By the equation—

$Zn + H_2SO_4 = ZnSO_4 + H_2$ it is indicated that an atom of zinc requires a molecule of absolute sulphuric acid in order to make a molecule of zinc sulphate, and two atoms [a molecule] of hydrogen.* Now if the atomic weight of Zn is 65.37, and the molecular weight of H_2SO_4 is 98, it follows that 65.37 parts by weight of Zn will require 98 parts by weight of H_2SO_4. And if the molecular weight of $ZnSO_4$ is 161.44, and the atomic weight of H is 1, 161.44 parts by weight of $ZnSO_4$ and 2 parts by weight of H will be the products of the reaction. Thus—

$$\begin{array}{l} Zn + H_2SO_4 = ZnSO_4 + H_2. \\ 65.37 + 98 \quad = 161.44 + 2. \end{array}$$

Problem.—How many Gm. of abs. H_2SO_4 is required to convert 50 Gm. of Zn into $ZnSO_4$?

Solution.—Since atomic and molecular weights may be considered as indicating parts by weight, the problem may be stated as follows:—if 65.37 parts of Zn require 98 parts of H_2SO_4, 50 Gm. of Zn will require how many Gm. of H_2SO_4? The parts, being parts by weight, are proportional to Gm., and the answer may be found by proportion in the usual manner, as follows:

The answer is to express weight [Gm.]; hence the known term expressing weight must be the third.

$$: \quad :: \quad 50 \text{ Gm.} \quad : \quad x$$

* In order that the reaction may occur as shown in the equation it is necessary that the acid used be diluted with considerable water, concentrated acid giving rise to other products, including SO_2 and H_2S. However, the water, though necessary, is the same on the product-side of the equation as on the factor-side, and hence does not enter into the calculations.

The answer is to be larger than 50 Gm., because the answer is to give the amount of H_2SO_4, and as it requires 98 parts of acid for 65.37 parts of Zn; i. e., it requires *more* acid than Zn, the answer will be larger than 50 Gm.

Hence—

65.37 parts : 98 parts :: 50 Gm. : x (75 Gm.).

Problem.—How many Gm. of Zn will 75 Gm. of absolute H_2SO_4 convert into $ZnSO_4$?

Solution.—Weight is asked for; hence the known term expressing weight must be the third. The answer is to be smaller than 75 Gm., because it requires less Zn than H_2SO_4. Hence—

98 parts : 65.37 parts :: 75 Gm. : x (50 Gm.).

In like manner—by proportion—the amount of $ZnSO_4$ formed may be calculated, as may also the amount of H evolved. Again, the amount of one of the products might be given. From it the amount of the other products may be calculated; also the amount of Zn, and the amount of H_2SO_4 required. In short, *if the quantity for any one member of an equation is given, the quantity for any other member may be found by proportion.*

It will be seen by close inspection that twelve distinct problems may be based on the equation given; and in case of equations of more than four members, the number of possible problems is correspondingly larger. Yet any and all may be solved by proportion, no specific rules being necessary. However, in order that there may be no mistake in selecting the terms for the proportion, the following procedure is recommended:

1. Write the equation for the reaction on which the problem is to be based.

2. Select the two members of the equation which figure in the problem; namely, (1.) the compound [or element] the quantity of which is *given* in the problem, and (2.) the compound [or element] the quantity of which is *sought.* Draw a line under each of the members of the equation thus selected; also indicate for which one the quantity is given and for which one it is sought.

3. Calculate the reacting weight for each of these two

members of the equation, writing the reacting weight under the lines.

The term reacting weight is here used to indicate the atomic weight, molecular weight, or multiple of these, as required by the equation. If, in the latter, the molecule is multiplied by a coefficient, the molecular weight must be multiplied by the same coefficient, and the product used in the proportion.

4. Select the third term. When quantity is asked for, the quantity given in the problem must constitute the third term. However, since the other values are weights—reacting weights, considered as parts by weight—the quantities must be in weight; for volumes are not proportional to parts by weight.

5. Select the second term. Reacting weights [parts by weight] are *directly* proportional. Hence the answer will be larger than the third term if the reacting weight of the substance, the quantity of which is sought, exceeds the reacting weight of the substance, the quantity of which is given. Or, in other words, the reacting weight of the substance, the quantity of which is sought, must be the second term.

6. Then the reacting weight of the substance, the quantity of which is given, must be the first term, and the general proportion will be as follows:

Reacting weight of substance quantity of which is given *is to* the reacting weight of the substance quantity of which is sought *as* the quantity given *is to* the quantity sought. This must be so, because the two values are *directly* proportional.

Application of Rule.

Problem.—How many Gm. of Zn are required to generate 30 Gm. of H?

Solution.—

1. Equation: $Zn + H_2SO_4 = H_2 + ZnSO_4$

2. Members required: $\underset{\textit{sought}}{Zn} + H_2SO_4 = \underset{\textit{given}}{H_2} + ZnSO_4$

3. Reacting weights required:

$$\left\{\begin{array}{lcl} Zn + H_2SO_4 = H_2 + ZnSO_4 \\ \textit{sought} & & \textit{given} \\ 65.37 & & 2 \end{array}\right.$$

4. Third term selected:

:   ::   30 Gm.   :   x.

5. Second term selected:

To generate 2 parts of H requires *more* than 2 parts of Zn; therefore the answer must be larger than the third term.

Then—

2 parts : 65.37 parts :: 30 Gm. : x (980.55 Gm.)

That is—

React. wt. H. : React. wt. Zn : : wt. H : wt. Zn.

It will be seen that the H and Zn alternate. This alternation of substances in the proportion—made necessary by the fact that the two values are *directly* proportional—may serve as proof that the first and second terms have been correctly placed.

Problem.—How many Gm. of ferric sulphate are required to make 100 Gm. of ferric hydroxide?

Solution.—Equation:

$$Fe_2(SO_4)_3 + 6NH_4OH = 2Fe(OH)_3 + 3(NH_4)_2SO_4.$$

sought   *given*

399.9   213.7

Then 213.7 parts : 399.9 parts :: 100 Gm. : x (187 Gm.).

R. wt. $Fe(OH)_3$: R. wt. $Fe_2(SO_4)_3$: : Wt. $Fe(OH)_3$: Wt. $Fe_2(SO_4)_3$.

Notice that the reacting weight of $Fe(OH)_3$ is twice its molecular weight [$106.86 \times 2 = 213.7$]; the equation showing that one molecule of $Fe_2(SO_4)_3$ will make two molecules of $Fe(OH)_3$.

Note.—On comparing the amounts given in the working formulas of text-books with the amounts of the factors as calculated from equations, great discrepancies will often be noticed. Thus, the amount of iron used in making FeI_2 is greatly in excess of the amount required by the equation. In like manner, ammonia water, when used to precipitate ferric salts, is used in

considerable excess. Practical experience has proven such excess necessary.
[For explanations the student is referred to the standard works on theoretical chemistry, especially to the chapters on mass action, on the ion theory, and on chemical equilibrium.] However, even in these instances the quantities as calculated from the equation, form a basis for the working formula.

Problems.

Some of the answers which follow were obtained with approximate atomic weights.

17. How much lime (CaO) can be made from 100 Gm. of marble ($CaCO_3$)? Ans. 56.4 Gm.

Equation: $CaCO_3 + \text{heat} = CaO + CO_2$.

18. How much carbon dioxide (CO_2) is formed at the same time?

19. How much absolute H_2SO_4 is required to neutralize 50 Gm. of absolute NaOH? Ans. 61.25 Gm.

Equation: $2\,NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O$.

20. How much Na_2SO_4 is formed? Ans. 88.75 Gm.

21. How much water is formed as a by-product?

22. How much $Ca\,(PH_2O_2)_2$ is required to make 2 oz. of KPH_2O_2? Ans. 715.2 gr.

Equation: $Ca(PH_2O_2)_2 + K_2CO_3 = 2KPH_2O_2 + CaCO_3$

23. How much $CaCO_3$ is formed as a by-product?

24. How many Gm. of silver nitrate can be made from 100 Gm. of silver?* Ans. 157.477 Gm.

Equation: $3\,Ag + 4HNO_3 = 3\,AgNO_3 + NO + 2\,H_2O$.

25. How much NO will be evolved? Ans. 9.2 Gm.

26. How much absolute HNO_3 will be used for the purpose? Ans. 77.85 Gm.

27. How much dried alum can be made from 50 Gm. of crystallized alum?

Note.—The dried alum is alum minus the water of crystallization.

28. Hydriodic acid may be made by the interaction of potassium iodide and tartaric acid, as follows:

$$KI + H_2C_4H_4O_6 = HI + KHC_4H_4O_6.$$

How much potassium iodide, and how much of tartaric acid, is required to make 50 Gm. of the hydriodic acid?

* In balancing oxidation and reduction equations employ Johnson's rule.

29. One pound of baking powder is to contain 9 oz. of cream of tartar, and enough baking soda for neutralization.* How much of the latter is required? Ans. 4.02 oz.

Equation:

$$KHC_4H_4O_6 + NaHCO_3 = KNaC_4H_4O_6 + CO_2 + H_2O.$$

30. How much carbon dioxide would a pound of this baking powder yield? Ans. 2.1 oz.

31. A druggist has use for 200 gr. of lithium citrate. He has none in stock, but has the carbonate. So he decides to make the citrate from the carbonate by saturation with citric acid. How much of the carbonate should he use? Ans. 105.7 gr.

Equation:

$$3Li_2CO_3 + 2H_3C_6H_5O_7 = 2Li_3C_6H_5O_7 + 3CO_2 + 3H_2O.$$

32. How much absolute mercuric oleate in 100 Gm. of official oleatum hydrargyri? How much uncombined oleic acid?

Note.—All HgO used is converted into oleate.

Equation: $HgO + 2HC_{18}H_{33}O_2 = Hg\ (C_{18}H_{33}O_2)_2 + H_2O$.

33. A druggist desires to make quinine bisulphate from the normal sulphate. How much absolute H_2SO_4 would be required by 100 Gm. of the normal salt? Ans. 11.256 Gm.

Equation: $(C_{20}H_{24}N_2O_2)_2H_2SO_4.7H_2O + H_2SO_4 + 7H_2O = 2C_{20}H_{24}N_2O_2H_2SO_4.7H_2O$.

Calculations Based on Reactions, but Involving Also Percentage Solutions.

From the equation, $3Hg + 8HNO_3 = 3Hg(NO_3)_2 + 2NO + 4H_2O$, the amount of *absolute* HNO_3 required to dissolve a given amount of Hg can be calculated by proportion. However, the acid which is actually used in the operation is not absolute HNO_3, but is an aqueous solution

*The rest is corn starch.

of the latter, 68% strong. A second calculation, in which it is determined how much 68% acid would be equivalent to [that is, would contain] the amount of absolute HNO_3 found by proportion, is therefore necessary, if the answer is to form the basis for practical work.

34. How many Gm. of nitric acid, 68% strong, are required to dissolve 20 Gm. of mercury as mercuric nitrate?

$$3Hg + 8HNO_3 = 3Hg(NO_3)_2 + 2NO + 4H_2O.$$

given *sought*

601.8 504.16

601.8 parts : 504.16 parts :: 20 Gm. : x (16.75 Gm.).

The answer indicates the amount of *absolute* HNO_3; and from this answer the amount of 68% acid containing 16.75 Gm. of absolute HNO_3 may be found by a second proportion. See chapter VI.

For this second proportion the three known terms are: 68%, 100% [the % of the abs. HNO_3], and 16.75 Gm. The answer is to express weight. Hence—

: :: 16.75 Gm. : x

The answer is to be *larger* than 16.75 Gm., because the question is, how much of a weaker acid is equivalent to 16.75 Gm. of absolute HNO_3. Hence—

68% : 100% :: 16.75 Gm. : x (24.63 Gm.).

Accordingly, 24.63 Gm. of official nitric acid is required to dissolve 20 Gm. of mercury. [In practice an excess is used.]

Note.—As has been stated before, dividing the divisor is equivalent to multiplying the dividend. It follows then that $(16.75 \text{ Gm.} \times 100) \div 68 = 16.75 \text{ Gm.} \div (68 \div 100)$. In other words, the amount of weaker acid may be found by dividing the amount of absolute acid by the percentage strength of the weaker acid, expressed in hundredths. Thus—

$$16.75 \text{ Gm.} \div .68 = 24.63 \text{ Gm.}$$

See page 70.

35. How many lb. of potassium acetate can be made from 50 lb. of acetic acid, 36% strong?

Remarks.—This problem may be solved in two ways: either the absolute acid in 50 lb. of the 36% acid may be

calculated, and this amount of absolute acid placed as the third term, in which case the fourth term will be the answer desired; or, the 50 lb. [of 36% acid] may be used as the third term, giving as the fourth term the amount of a 36% solution of potassium acetate, from which, by a subsequent calculation, the amount of [absolute] potassium acetate may be found.

Solution, the first-mentioned process being used.—

100% : 36% :: 50 lb. : x (18 lb.),

showing that the 50 lb. of 36% acid contain 18 lb. of absolute acid.

The problem has thus been simplified to—How much $KC_2H_3O_2$ can be made from 18 lb. of $HC_2H_3O_2$?

Equation:

$$HC_2H_3O_2 + KHCO_3 = KC_2H_3O_2 + CO_2 + H_2O.$$

given	*sought*
60.03	98.12

Then— 60.03 parts : 98.12 parts :: 18 lb. : x
x = 29.4 lb. = wt. of $KC_2H_3O_2$.

36. How many Gm. of $Na_2CO_3.10H_2O$ must be used to make 500 Gm. of 5% solution of NaOH?

Solution.— 100% : 5% :: 500 Gm. : x (25 Gm.), showing that the 500 Gm. of solution contain 25 Gm. of NaOH.

Equation:

$$Na_2CO_3.10H_2O + Ca(OH)_2 = 2NaOH + CaCO_3 + 10H_2O$$

sought	*given*
286.16	80.02

80.02 parts : 286.16 parts :: 25 Gm. : x (89.4 Gm.).

37. A druggist desires to prepare 250 Gm. of dil. HBr (10%) by the tartaric acid method. How much KBr and how much $H_2C_4H_4O_6$ are required? Ans. 36.73 Gm. of KBr and 46.33 Gm. of the acid.

Equation: $KBr + H_2C_4H_4O_6 = HBr + KHC_4H_4O_6$.

38. HCN may be made extemporaneously from AgCN and HCl. How much hydrochloric acid, 31.9% strong, would be required by 1 oz. of silver cyanide?

Equation: $AgCN + HCl = AgCl + HCN$.

39. How many gr. of dil. HCN (2% strong) would be produced?

40. How much stearic acid, and how much crystallized sodium carbonate are required to make 500 Gm. of glycerin suppository mass, the latter to contain 4% of sodium stearate as stiffening agent?

Solution: 4% of 500 = 20 Gm. (amt. of sodium stearate required).

Equation:

$$2HC_{18}H_{35}O_2 + Na_2CO_3.10H_2O = 2NaC_{18}H_{35}O_2 + CO_2 + 11H_2O$$

sought 568.58 — *given* 612.58

Then— 612.58 : 568.58 :: 20 Gm. : x

R. wt. sod. stear. : R. wt. st. ac. :: wt. sod. st. : wt. st. ac.

And in like manner the amt. of sodium carbonate is found.

React. wt. sodium stearate : react. wt. sodium carbonate :: 20 Gm. : x.

41. How much $HgCl_2$ is required to yield enough yellow mercuric oxide for ½ lb. of stock ointment 40% strong?*

Equation: $HgCl_2 + 2NaOH = HgO + 2NaCl + H_2O$.

* If the right amount of the oxide is precipitated, it is but necessary to wash, drain, and mix with enough wool fat to make ½ lb. of stock ointment, which may be quickly diluted as needed, yielding an ointment far superior to that made from the dried oxide by trituration.

Problems Involving also Reduction of Volume to Weight and Vice Versa.

42. How many grains of Zn would be converted into $ZnCl_2$ by 200 c.c. of hydrochloric acid, sp. gr., 1.16, strength, 30%?

Solution.— 200 c.c. [$\times$ 1.16] = 232 Gm.

100% : 30% : : 232 Gm. : x (69.6 Gm. of abs. HCl).

Equation:— $Zn + 2HCl = ZnCl_2 + H_2$.
sought *given*
65.37 72.94

Then—
72.94 parts : 65.37 parts :: 69.6 Gm. : x (62.4 Gm. of Zn).

43. How many gr. of Li_2CO_3 would be dissolved as LiCl by 1 f℥ of hydrochloric acid, sp. gr., 1.158, strength, 31.9%? Ans. 171 gr.

Equation: $Li_2CO_3 + 2HCl = 2LiCl + CO_2 + H_2O$.

44. How many c.c. of nitric acid, sp. gr., 1.403, strength, 68%, can be made from 600 Gm. of $NaNO_3$? Ans. 465.8 c.c.

Equation:—$NaNO_3 + H_2SO_4 = NaHSO_4 + HNO_3$.

45. How many c.c. of sulphuric acid, sp. gr., 1.826, strength, 92.5%, would be required by the 600 Gm. of $NaNO_3$?

46. How many f℥ of ammonia water, sp. gr., .897 strength, 28%, could be neutralized with 500 c.c. of acetic acid, sp. gr., 1.045, strength, 36%?

Solution.—

Step I: Finding amount of *absolute* acetic acid.

500 $\times$ 1.045 (sp. gr.) = 522.5 Gm. (wt. of acid).

Then 100% : 36% : : 522.5 Gm. : x (188.1 Gm. of absolute acetic acid.)

Step II: Finding amount of abs. ammonia (NH_3) this amount of abs. acid would neutralize.

Equation:— $NH_3 + HC_2H_3O_2 = NH_4C_2H_3O_2$.

		sought	*given*			
		17.03	60.03			
60.03	:	17.03	::	188.1 Gm.	:	x

x = 53.32 Gm. (am't of NH_3 neut. by 188.1 Gm. of abs. acid).

Step III: Finding Gm. of 28% ammonia water equal to 53.32 Gm. of abs. NH_3.

28% : 100% :: 53.32 Gm. : x (190.43 Gm.).

Step IV: Reducing weight in Gm. to volume in f℥.

190.43 ÷ .897 (sp. gr.) = 212.3 c.c.
And 212.3 c.c. ÷ 29.57 = 7.2 f℥. (Ans.)

Problems Based on Gravimetric Analyses.

Problems based on equations occur not only in manufacturing, but also in analytical chemistry.

For instance:

47. 1.2 Gm. of crude barium hydroxide is dissolved by aid of HCl; the resulting $BaCl_2$ precipitated as a sulphate—as $BaSO_4$, and the latter washed, dried and weighed. Its weight is found to be 1.6 Gm. What % of $Ba(OH)_2$ in the sample?

Equation:
$$Ba(OH)_2 + 2HCl = BaCl_2 + 2H_2O$$
$$BaCl_2 + H_2SO_4 = BaSO_4 + 2HCl.$$

Solution: It will be seen that a molecule of $BaSO_4$ requires for its production a molecule of $Ba(OH)_2$. Hence 233.44 parts (mol. wt. of $BaSO_4$) of the precipitate indicate 171.37 parts (mol. wt. of $Ba(OH)_2$). And since all the $Ba(OH)_2$ in the sample has been converted into $BaSO_4$, the calculation is:

233.44 parts : 171.37 parts :: 1.6 Gm. : wt. of $Ba(OH)_2$ in sample.

Then weight of sample (1.2 Gm.) : wt. of $Ba(OH)_2$ in sample :: 100% : x.

N. B.—Use the general rules for stating proportions.

48. .6 Gm. of a certain iron ore is dissolved in HCl, oxidized to ferric iron with HNO_3, precipitated as ferric hydroxide, ignited to ferric oxide, yielding of the latter .52 Gm. What % of iron in the ore?

Solution: All the iron in the sample (.6 Gm.) is found in the ignited precipitate, existing in the latter as Fe_2O_3. If we find the amount of iron (Fe) in the .52 Gm. of Fe_2O_3, we have therefore also the amount in the .6 Gm. of ore.

Mol.wt.Fe_2O_3 : mol.wt.Fe_2 : : .52Gm. : x (Fe in precip.).

.6 Gm. : x : : 100% : y. (% of Fe in ore). Ans. 60.5%.

49. .5 Gm. of a certain phosphate yield .13 Gm. of $Mg_2P_2O_7$. Calculate the % of phosphorus in the phosphate.

50. Calculate the % of PO_4.

51. This would equal how much P_2O_5?

Note.—$Mg_2P_2O_7 = P_2 = 2\,PO_4 = P_2O_5$.

Calculating the Analytical Factor.

In the preceding problems the calculations were based upon combining weights, which formed the first couplet of the proportion in each case.

If a large number of determinations of the same kind are to be made, the above calculations may be shortened by the use of factors.

The analytical factor is simply the ratio between the first and second terms of the proportion based upon the combining weights, and is used as a multiplier of the final weight in the gravimetric analysis, giving as product the corresponding weight of substance to which the laboratory results are to be calculated.

For instance: A number of phosphorus determinations are to be made, and the phosphorus is to be weighed as

$Mg_2P_2O_7$. In the proportion the first couplet would be

$$Mg_2P_2O_7 : P_2 = \frac{P_2}{Mg_2P_2O_7} = \frac{62.08}{222.72}.$$

If the ratio be found, $62.08 \div 222.72 = .277$, this may be used as a factor, and will give the amount of P_2 in any known amount of $Mg_2P_2O_7$ by multiplication. If the weight of $Mg_2P_2O_7$ is .2 Gm., it will contain .2 Gm. $\times$ .277 = .0554 Gm. of phosphorus.

53. Iron, Fe_2, is to be determined as Fe_2O_3. What factor may be used?

54. CaO is to be determined as $CaCO_3$. Calculate factor.

55. Use factor in calculating amount of CaO indicated by .2 Gm. of $CaCO_3$.

Problems Based on Volumetric Analyses.

Normal Solutions.

A normal, $\frac{N}{1}$, ***volumetric solution*** contains in each Liter the chemical equivalent of 1 Gm. of hydrogen. In other words, the quantity of the substance required to make 1 L. of normal solution is the molecular weight, expressed in Gm., and divided by the number indicating how many times the molecule is equivalent to H_1. In case of acids, the basicity indicates the equivalence; and accordingly the molecular weight of HCl is divided by 1 (that is, is not divided at all); H_2SO_4 is divided by 2; H_3PO_4 by 3; etc. In case of bases, the valence of the metal or basylous radical gives the divisor. Thus, NaOH is divided by 1, $Ba(OH)_2$ by 2, etc. In case of precipitants, the valencies of the radical which recurs in the precipitate shows the equivalence. Thus NaCl, when it precipitates AgCl, equals Cl′, hence NaCl = H_1. The following substances are equivalent to H_1 : — HCl, NaOH, KOH, I, Br, KSCN, $AgNO_3$, NaCl, $Na_2S_2O_3$.

The following are equiv. to H_2 : H_2SO_4, $H_2C_2O_4 . 2H_2O$, $Ba(OH)_2$, $BaCl_2$.

$K_2Cr_2O_7 = O_3$; hence $= H_6$. $2KMnO_4 = O_5$; hence $= H_{10}$.

Problem.—How much absolute H_2SO_4 is required for 1 L. of $\frac{N}{1}$ H_2SO_4?

Solution.—Mol. wt. $H_2SO_4 = 98.09$ ∴ 98.09 Gm. ÷ 2 = 49.045 Gm. (Ans.).

Adjusting Strength of Normal Solutions.

All normal solutions will, if they react, be equal to each other volume for volume. If then, one $\frac{N}{1}$ solution of standard strength is at hand, a normal solution of a reagent capable of reacting with the solution on hand, can be made by comparison, that is, can be standardized against the first solution.

For instance: A certain solution of H_2SO_4 requires for the neutralization of 10 c.c. 12 c.c. of $\frac{N}{1}$ KOH. To what volume must 400 c.c. of the acid solution be diluted to make 1 L. of $\frac{N}{1}$ strength?

Solution.—If 10 vol. of the H_2SO_4 solution required 12 vol. of $\frac{N}{1}$ KOH, then the 10 vol. contain as much H_2SO_4 as should be contained in 12 vol. of $\frac{N}{1}$ H_2SO_4, and 10 volumes must be diluted to 12 volumes.

Hence— 10 vol. : 12 vol. :: 400 c.c. : x (480 c.c.), which is the volume to which the 400 c.c. should be diluted. See chapter vii.

Fractional Normal Solutions.

There are also solutions $\frac{1}{2}$, $\frac{1}{5}$, $\frac{1}{10}$, $\frac{1}{50}$ and $\frac{1}{100}$ of normal strength, and are known as half-normal, fifth-normal, deci- or tenth-normal, fiftieth-normal, centi- or hundredth-normal respectively.

Volumetric Factors.

The normal factor of a substance is the amount in 1 c.c. of a $\frac{N}{1}$ solution of that substance. Thus the normal factor of $H_2SO_4 = (98.09$ Gm. $\div 2) \div 1000 = .049045$ Gm.

The deci-normal factor is the amount in 1 c.c. of a deci-normal solution. In like manner we may define $\frac{N}{2}$, $\frac{N}{5}$, $\frac{N}{50}$, and $\frac{N}{100}$ factors.

As all $\frac{N}{1}$ solutions are equivalent c.c. for c.c. (if they react), it follows that the normal factor of a substance is also the amount *indicated* by 1 c.c. of a $\frac{N}{1}$ solution of the opposite kind.

For instance: 1 c.c. $\frac{N}{1}$ HCl will just neutralize 1 c.c. of $\frac{N}{1}$ NaOH. Then if a quantity of NaOH is just neutralized by 1 c.c. of $\frac{N}{1}$ HCl, it must contain as much absolute NaOH as 1 c.c. of $\frac{N}{1}$ NaOH solution. That is, the $\frac{N}{1}$ factor indicates the amount of abs. NaOH in the sample. Upon this deduction is based the method of calculating results from volumetric analyses.

All this applies, of course, also to fractional normal solutions and to fractional normal factors.

Problems.

56. Calculate the amount of $AgNO_3$ in 1 L. of $\frac{N}{1}$ $AgNO_3$ solution.

57. Calculate the amount of $K_2Cr_2O_7 (= H_6)$ for 500 c.c. of solution.

58. Calculate the amount of H_2SO_4 in 200 c.c. of $\frac{N}{5}$ solution.

59. Calculate the $\frac{N}{1}$ factor for $H_2C_2O_4.2H_2O$.

Solution.—Mol. wt. $= 126.05$. A dibasic acid, hence $= H_2$ $\therefore (126.05 \div 2) \div 1000 = .063025$, $\frac{N}{1}$ factor.

60. Calculate $\frac{N}{1}$ factor for (a.) KOH, (b.) $AgNO_3$, (c.) $Ba''Cl_2$, (d.) $K_2Cr_2O_7$.

61. Calculate the $\frac{N}{10}$ factor for (a.) I, (b.) $Na_2S_2O_3$, (c.) $2KMnO_4$ $(= H_{10})$.

62. Calculate the $\frac{N}{50}$ factor for strychnine, $C_{21}H_{22}N_2O_2$, equivalent to H_1. Ans. 0.00668.

Use of Normal and Fractional Normal Factors.

Suppose 1 Gm. of a commercial sulphuric acid requires for neutralization 20 c.c. of $\frac{N}{1}$ KOH. Then the 1 Gm. of acid contains as much absolute H_2SO_4 as 20 c.c. $\frac{N}{1}$ solution; that is, $\frac{N}{1}$ factor of $H_2SO_4 \times 20 = .049045$ Gm. $\times 20 = .9809$ Gm. It will be observed that the factor to be used is the factor of the substance to be determined,—not the factor of the volumetric solution used in the titration.

Problem.—2.5 Gm. of commercial ferrous sulphate is dissolved to make 60 c.c. of solution. 12 c.c., which is 1-5 of this solution, require 17 c.c. of $\frac{N}{10}$ potassium permanganate for complete oxidation. (a.) Calculate amount of $FeSO_4.7H_2O$ in sample. (b.) Calculate to percentage.

Solution.—

Mol. wt. of $FeSO_4.7H_2O = 278$. $FeSO_4.7H_2O = H_1$
$\therefore 278 \div 10{,}000 = .0278$ Gm. ($\frac{N}{10}$ factor).
And .0278 Gm. $\times 17 = .4726$ Gm. (amt. of $FeSO_4.7H_2O$ in 1-5 of sample weighed out, i. e., in .5 Gm.)
Then .5 Gm. (wt. of test sample) : .4726 Gm. :: 100% : (x) 94.5%.

CALCULATING A CORRECTION FACTOR.

Some volumetric solutions, like deci-normal $KMnO_4$, become weaker on keeping. Instead of fortifying to standard strength, which is very difficult, a correction factor may be calculated, and used as a multiplier of the volume of volumetric solution used. Suppose a $KMnO_4$ solution has weakened so that 10 c.c. oxidize only as much iron as 9 c.c. of deci-normal $KMnO_4$ solution. If then the volume of volumetric solution used in a titration is first multiplied by .9, the deci-normal factor of the substance tested may be employed in the usual way. The correction factor is therefore a number which expresses the strength of a solution, with reference to the normal or fractional normal strength, which is taken as unity.

Example.—A solution of $Ba(OH)_2$, originally of deci-normal strength, has weakened owing to absorption of CO_2, so that 10 c.c. of it neutralize only 9.2 c.c. of deci-normal HCl. This $Ba(OH)_2$ solution is used in the titration of commercial acetic acid .5 Gm of which required 20 c.c. of the $Ba(OH)_2$ solution. Calculate amount of absolute $HC_2H_3O_2$ in the acid.

Solution.—Since 10 c.c. of $Ba(OH)_2$ solution $= 9.2$ of deci-normal solution, 20 c.c. of $Ba(OH)_2 = 18.4$ c.c. of deci-normal $Ba(OH)_2 \therefore .006$ Gm. (deci-normal factor $HC_2H_3O_2$) $\times 18.4 = .1104$ Gm. (amt. of abs. acetic acid).

CHAPTER X.

REDUCING VOLUMES OF GASES TO WEIGHTS AND VICE VERSA.

If the molecular weight of a gas, based upon $O=16$, is expressed in Gm., and this weight of the gas is measured, under standard conditions of temperature and pressure, the volume is in every case about 22.4 L. Thus, 32 Gm. of O_2, 2 Gm. of H_2, 28 Gm. of N_2, each measure 22.4 L.; so do 48 Gm. of O_3 (ozone), 44 Gm. of CO_2, and 17 Gm. of NH_3. This is in conformity with Avogadro's law, that all gases contain the same number of molecules in equal volumes, under identical conditions of temperature and pressure.

Accordingly, the weight of a given volume of any gas (of known molecular weight) may be calculated; so, also, the volume of a given weight.

This may be done by *proportion.*

As the weights and volumes are *directly* proportional (4 Gm. of H measuring twice as much as 2 Gm.) the general proportion for the determination of weight from volume would be:

22.4 L. : observed vol. in L. :: mol. wt. of gas in Gm. : x.

x = wt. in Gm. of observed volume.

And the general proportion for the calculation of the volume of a definite weight of any gas would be:

mol. wt. of gas in Gm. : observed wt. in Gm. :: 22.4 L. : x

x = vol. of gas in L.

The general rule for the statement of the proportion may be used, as in the following examples.

1. What is the volume of 500 Gm. of oxygen?

Solution.—Mol. wt. of $O = 16 \times 2 = 32$.

Then the three known terms for the proportion are: 32 Gm., 500 Gm. and 22.4 L.

The answer is to express volume. Hence—

: :: 22.4 L. : x

The values being directly proportional, and the weight for which the volume is to be found being *larger* than the weight for which the volume is known [the molecular weight, expressed in Gm.], the answer will be *larger* than the third term. Hence—

32 Gm. : 500 Gm. :: 22.4 L. : x (350 L.).

2. What is the weight of 50 L. of NH_3?

Solution.—Mol. weight of $NH_3 = 17$.

Then the three known terms are—17 Gm., 50 L., and 22.4 L.

The answer is to express weight. Hence—

: :: 17 Gm. : x

The answer is to be larger than the third term. Hence—

22.4 L. : 50 L. :: 17 Gm. : (38 Gm.).

Problems.

3. What is the volume of 1 Kg. of O? of 50 Gm. of CO_2? of 30 Gm. of H_2S? of 5 Gm. of Cl?

4. What is the weight of 50 L. of SO_2? of 10 L. of N_2O (laughing gas)? of 1 gallon of O? of 300 c.c. of H?

Note.—Oxygen, chlorine, and hydrogen have two atoms in the molecule; hence the molecular weight is, for each of these elements, double the atomic weight.

Effect of Variation in Pressure on the Volume of a Gas.

When the pressure upon a gas is increased, the volume of the gas is found to decrease correspondingly. If the pressure is doubled, the volume of the gas is thereby reduced to one-half the initial volume; if the pressure is tripled, the volume of the gas is reduced to one-third; if

the pressure is reduced to one-half the initial pressure the volume of the gas becomes twice the initial volume; etc.

Boyle's Law.—The relation of pressure to volume is stated by Boyle as follows: With the temperature constant, the volume of any given weight of any gas varies inversely as the pressure upon it.

It follows then that if the volume has been observed at any given pressure, the volume which the gas would occupy at any other pressure may be calculated by proportion.

5. The NO gas, evolved from a certain amount of ethyl nitrite, measures 60 c.c. at a pressure of 744 mm.* How much would it measure at 760 mm?

Solution.—Volume is asked for. Hence—

: : : 60 c.c. : x

The values being inversely proportional, the NO would measure *less* at 760 mm. than at 744 mm. The answer is therefore to be *smaller* than the third term. Hence—

760 mm. : 744 mm. : : 60 c.c. : x (58.73 c.c.)

Problems.

6. A Liter of ammonia gas at normal pressure, would measure how much at a pressure of two atmospheres? Ans. .5 L.

7. A quantity of CO_2, which measures 84.5 c.c. at 751 mm., will measure how much at normal pressure?

8. A quantity of O, measuring 3 gallons at 760 mm., would measure how much at 1.520 M? Ans. $1\frac{1}{2}$ gal.

9. What would be the volume of 3 Gm. of SO_2 at 748 mm.

Note.—Remember that the volume of the "gramme-molecule" is 22.4 L. at normal pressure only.

*Note.—Pressure of gases is expressed in units of length, the expression having reference to the height of a column of mercury which will have an equal pressure. Thus, a pressure of 760 mm. is a pressure capable of supporting (hence equal to) a column of mercury 760 mm. high. 760 mm. is the atmospheric pressure under standard conditions; and is known as normal pressure, or as one atmosphere. Two atmospheres would therefore equal 760 mm. × 2.

10. What is the weight of 500 c.c. of Cl, measured at a barometric pressure of 752 mm. Ans. 1.554 Gm.

Note.—When a gas is collected over a liquid, as N_2O over water, the pressure of the gas is equal to the atmospheric pressure—i. e., barometric pressure.

Effect of Variation in Temperature on the Volume of a Gas.

The standard temperature for measuring gases is 0°C. If the volume is taken at a different temperature [for sake of convenience], the volume at 0°C. must be calculated from the observed volume before the constant, 22.4 L., can be made use of.

With the pressure remaining unchanged, the volume of a gas varies directly as its absolute temperature.*

By absolute temperature is meant temperature reckoned from 273°C. below 0°C. In other words, the zero of absolute temperature is minus 273°, or —273°C. It follows then that temperature in °C. may be reduced to absolute temperature by adding 273°†. Thus, 15°C. is $273 + 15 = 288$°C. absolute temperature; and 100°C. is $273 + 100 = 373$°C absolute temperature.

11. A pharmacist in assaying spt. of nitrous ether has obtained a volume of NO gas measuring 56 c.c. at a temperature of 22°C. What is the volume of the gas at 0°C.?‡

Solution.— $22°C = 273 + 22 = 295°C.$ abs. temp.

$0°C. = 273 + 0 = 273°C.$ abs. temp.

The three known terms are: 295°C [absolute temperature at which volume was observed], 273°C [absolute temperature at which volume is wanted], and 56 c.c. [observed volume.]

The answer is to express volume. Hence—

$$: \quad :: \quad 56 \text{ c.c.} \quad : \quad x$$

As the volume varies *directly* with the temperature;

*This "law" is not exactly true for all gases.

†For directions for adding a positive quantity to a negative quantity (for instance, 273°C. to —20°C.), see chapter XI.

‡In the U. S. P., 9th Rev., the gasometric assays have been simplified by the use of factors based on volume of gas at 25°C. But the methods of general gasometric analysis involve the above calculations.

and as the temperature at which the volume is wanted is *lower* than the temperature at which the volume is known, the answer must be *smaller* than the third term. Hence—

295°C : 273°C : : 56 c.c. : x(51.8 c.c.)

The general proportion would be:

Absolute temperature at which volume was observed *is to* absolute temperature at which volume is wanted [273°C + 0°C. = 273°C.] *as* observed volume *is to* x.*

Problems.

12. A quantity of CO_2 measures 35 c.c. at 20°C. What will it measure at 0°C.? Ans. 32.6 c.c.

13. A quantity of hydrogen measures 5 L. at 23° C. What would be its volume at 0°C.? What at 50°C? What at 100°C.?

14. A quantity of NO measures 60 c.c. at a pressure of 750 mm., and at a temperature of 20°C. What would be its volume at normal pressure and temperature.

Solution.— 760 mm. : 750 mm. : : 60 c.c. : x
x = 59.21 c.c. = vol. at normal pressure.
Then 273 + 20°C. : 273 + 0°C. : : 59.21 c.c. : x
x = 55.16 c.c. = vol. at normal pressure and temperature.

15. What is the *weight* in Gm. of 60 c.c. of NO gas, measured at a barometric pressure of 750 mm., and at a temperature of 20°C.?

Solution.—Having found the volume of the gas at normal pressure and temperature, as shown in the preceding example, we calculate the *weight* of that volume [in this case, 55.16 c.c.] of NO thus:

22.4 L. : .05516 L. :: 30 Gm. [mol. wt. of NO] : x. x = .074 Gm.

16. How much $C_2H_5NO_2$[ethyl nitrite] is indicated by 60 c.c. of NO at a pressure of 750 mm., and at a temperature of 20°C.?

*It will be seen that a gas at 0°C. expands $\frac{1}{273}$ of its volume for an increase in temperature of 1°C.; and that it contracts $\frac{1}{273}$ of its volume for a decrease in temperature of 1°C.; in short, that the coefficient of expansion of any gas is $\frac{1}{273}$, or, decimally, .003665.

Solution.—Having calculated the *weight* of the NO, we calculate the amount of $C_2H_5NO_2$ required to produce the weight [in this case, .074 Gm.] of NO gas.*

Equation:

$C_2H_5NO_2 + KI + H_2SO_4 = NO + C_2H_5OH + KHSO_4 + I.$

sought *given*

75.05 30

Then—

30 parts : 75.05 parts :: .074 Gm. : x (.185 Gm.).

17. How many c.c. of CO_2, at normal pressure, and at a temp. of 25°C., would be generated from .5 Gm. of $NaHCO_3$?

Equation: $2NaHCO_3 + H_2SO_4 = Na_2SO_4 + 2CO_2 + 2H_2O$.

18. How many L. of hydrogen [pressure, 748 mm., temp., 20°C.] could be made from 5 Gm. of zinc?

19. How much $KClO_3$ is required to generate 25 L. of O.?

Equation: $2KClO_3 = 2KCl + 3O_2$.

Note.—If pressure and temperature are not given, normal pressure and temperature are understood.

20. How much NH_4NO_3 is required to make 10 gallons of N_2O [laughing gas]?

Equation: $NH_4NO_3 = N_2O + 2H_2O$.

21. How much NH_4NO_3 is required to make enough N_2O to fill a 10 gallon tank, the temperature being 20°C., and the barometric pressure, 750 mm.?

For equation see problem No. 20.

22. A certain quantity of baking powder yielded 70 c.c. of CO_2;—temp., 20°C., pressure, 748 mm. How much $NaHCO_3$ did the quantity of baking powder contain? Ans. .24 Gm.

Equation: $NaHCO_3$ + acid = CO_2 etc.

24. How many c.c. of ammonia water, sp. gr. .96, strength, 10%, would contain 5L. of NH_3 gas?

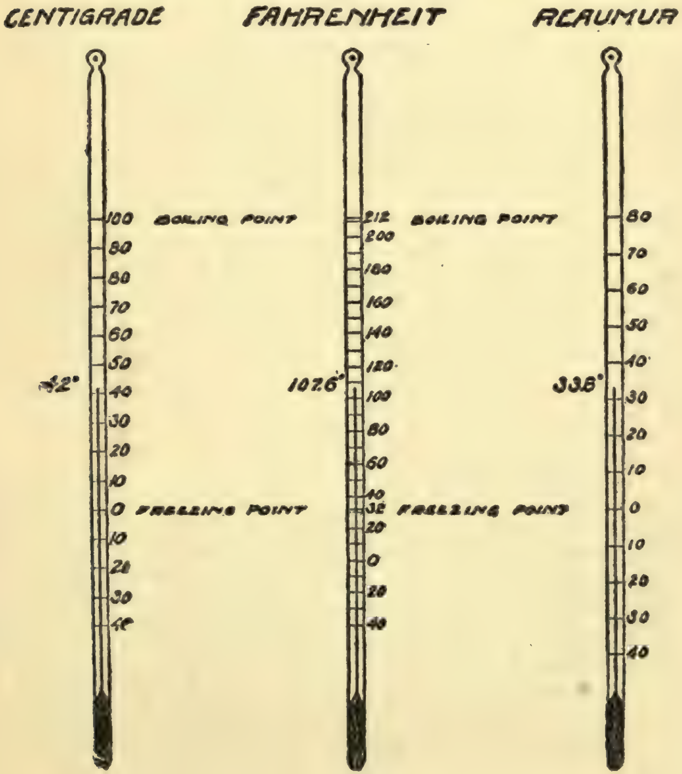
*In the U. S. P., 9th Rev., a factor is used to simplify this calculation. See "factors" page 128.

CHAPTER XI.

THERMOMETER SCALES.

On a Centigrade thermometer the temperature of melting ice [freezing point of water] is zero; and the temperature of steam, at normal pressure [boiling point of water], is 100.

On a Fahrenheit thermometer the temperature of



melting ice is 32 above zero; and the temperature of steam, at normal pressure, is 212.

On a Reaumur thermometer the temperature of melting ice is zero; and that of steam, at normal pressure, is 80.

On all three thermometers the graduation is continued above the boiling point, and below the zero point.

Temperature in degrees below zero, on any scale, is expressed as a negative quantity, the minus sign being placed before the number thus, $-45°$, which means $45°$ below zero. If the minus sign is absent, the number is *understood* to be a positive number, and to denote degrees above zero.

Centigrade to Fahrenheit.

It will be seen that $100°C = 180°F. = 80°R.$; and hence that $1°C. = 1.8°F = .8°R.$

Problem.—Convert 60°C. into °F.

Solution.—Since $1°C. = 1.8°F.$, $60°C = 60° \times 1.8 = 108°F.$ But since 60°C. means 60° above the freezing point, the 108°F. must be counted from that same point; and as the freezing point is marked 32 on the F. scale, 32 must be added to 108 in order to get the reading counting from zero F. Accordingly, $108° + 32° = 140°$; and $60°C. = 140°F.$ Whence the rule—

$$(°C. \times 1.8) + 32 = °F.$$

Problem.—Convert $-25°C.$ into °F.

Solution. $-25 \times 1.8 = -45$. [Remember that when a negative quantity is multiplied by a positive quantity, the product is a negative quantity.] It will thus be seen that 25 divisions on the C. scale equal 45 on the F. scale. But since the freezing point on the F. scale is 32° above zero, and since the °C. are counted from the freezing point, the temperature of $-25°C.$ would be $-45° + 32$; *which means that the reading would be 32° higher on the F scale than $-45°$*, hence would be $[-45 + 32]$ $-13°F.$

The rule for adding a positive quantity to a negativ

quantity is as follows: Subtract the smaller number from the larger, and read the remainder with the sign of the larger number. Thus, $-10 + (+32) = +22$; $-42 + (+32) = -10$.

Problem.—Convert —10°C. into °F.

Solution. $-10^\circ \times 1.8 = -18^\circ$.

And $-18 + (+32) = +14$. Hence $-10^\circ C = 14^\circ F$.

Note.—To add 32 means that the reading is to be 32° higher on the scale.

Fahrenheit to Centigrade.

Problem.—Convert 60°F. into °C.

Solution.—The first step to be taken is to find what would be the reading on the Fahr. thermometer if the freezing point were zero. This reading would be 32° lower than 60°, for zero on the Fahr. thermometer is 32° below the freezing point. Accordingly, we subtract 32° from 60°.

We have now ascertained that the temperature of 60° F. equals 28° assuming the zero point to be where it is on the Centigrade thermometer, namely at the freezing point.

Now 1°C. = 1.8° F.; then 28° F. must equal as many degrees C. as 1.8 is contained in 28°. Accordingly, we divide 28° by 1.8:

$$28^\circ \div 1.8 = 15.5^\circ \text{ C.}$$

Whence the rule—

$$(^\circ\text{F.} - 32) \div 1.8 = {}^\circ\text{C.}$$

Problem.—Convert 10° F. into °C.

Solution.—If the zero on the Fahr. thermometer were at the freezing point [where it is on the Centigrade thermometer], the reading would be 32° lower than 10°, hence would be —22°.

Then $\quad -22^\circ \div 1.8 = -12.2^\circ\text{C.}$ (Ans.)

Problem.—Convert —10°F. into °C.

Solution.—If the zero on the Fahr. thermometer were at the freezing point [as in the Centigrade scale], the reading would be 32° lower on the scale than —10°, hence would be —42°.

Then $$-42° \div 1.8 = -23.3° C.$$

Note.—It will be seen that (+32) is subtracted from a positive quantity [from an above zero reading] smaller than 32 by finding the difference between that positive quantity and 32; that difference being a negative quantity, i. e., a reading beyond [below] the zero point.

And that (+32) is subtracted from a negative quantity [from a below zero reading] by adding 32 to the negative quantity, and calling the sum a negative quantity.

In short, **to subtract 32 means to find the reading 32° lower on the scale.**

CENTIGRADE AND REAUMUR.*

Problem.—Convert 15°C. into °R.

Solution.— 100° C. = 80° R. Then 1°C. = .8° R.

And 15°C. = 15 × .8 = 12° R.

Whence the rule—

$$°C. \times .8 = °R.$$

Problem.—Convert 15° R. into °C.

Solution.—Since .8°R.=1.°C.,15°R.=15°÷.8=18.7°C.

Whence the rule—

$$°R. \div .8 = °C.$$

FAHRENHEIT AND REAUMUR.

Problem.—Convert 60°R. into °F.

Solution.—Since 80°R. = 180° F., 1°R. = 2.25° F.

And 60° R. = 60 × 2.25 = 135°F. But since the zero of the R. scale is at the freezing point, the 135°F. must be counted from the same point. Hence 135° + 32° = 167°F.

Whence the rule—

$$(°R. \times 2.25) + 32 = °F.$$

*The Reaumur scale is not used in the United States, and is of interest only because temperature is expressed in °R. in some European publications.

Problem.—Convert 61°F. into °R.

Solution.– 61°F. = 61 — 32 = 29°F. above the freezing point. Then 29° ÷ 2.25 = 12.2°R.

Whence the rule—

(°F.—32) ÷ 2.25 = °R.

Problems.

1. Convert (a.) 25°C. into °F.; (b.) 80°C. into °F.
2. (a.) 5°C into °F.; (b.) —5°C. into °F.
3. (a.) —30°C. into °F.; (b.) 2.5°C. into °F.
4. (a.) —2.5°C. into °F.; (b.) 1.1°C. into °F.
5. (a.) 125°F. into °C.; (b.) 25°F. into °C.
6. (a.) 5°F. into °C.; (b.) 5.8°F. into °C.
7. (a.) —5°F. into °C.; (b.) —1.1°F. into °C.
8. (a.) —25°F. into °C.; (b.) 31° F. into °C.
9. (a.) 10°C. into °R. (b.) 10°R. into °C.
10. (a.) —10°C. into °R. (b.) 10°C. into °R.
11. (a.) —10°R. into °C. (b.) 1.1°R. into °C.
12. (a.) 25°F into °R. (b.) 25°R. into °F.
13. (a.)—25°F. into °R. (b.)—25°R. into °F

Answers.

1. (a.) 77°F.; (b.) 176°F. 2. (a.) 41°F.; (b.) 23°F. 3. (a.) —22°F.; (b.) 36.5°F. 4. (a.) 27.5°F.; (b.) 33.98°F. 5. (a.) 51.66°C. 6. (a.) —15°C. 7. (a.) —20.5°C. 8. (a.) —31.6°C.

MISCELLANEOUS.

BEAUMÈ HYDROMETER SCALES.

(a.) For Liquids heavier than water.

Rule: Subtract the observed degrees Beaumè from 145, and divide the remainder into 145. The answer is the sp. gr.

$$\text{Sp. gr.} = 145 \div (145 - {}^\circ\text{B})$$

Problem.—A certain carboy of hydrochloric acid is marked 20° B. What is its sp. gr.?

Calculation.— $145 - 20 = 125$; $145 \div 125 = 1.16$ (sp. gr.)

(b.) For liquids lighter than water.

Rule: Add the observed degrees Beaumè to 130, and divide the product into 140. The answer is the sp. gr.

$$\text{Sp. gr.} = 140 \div (130 + {}^\circ\text{B})$$

Problem.—Ammonia water, marked 26° B., has what sp. gr.?

Calculation.— $130 + 26 = 156$; $140 \div 156 = .8974$ sp. gr.

PROBLEMS.

1. Reduce to sp. gr. the following degrees B. on scale for liquids heavier than water:—(a.) 18°B.; (b.) 25°B.; (c.) 30°B.; (d.) 50°B.

2. Reduce to sp. gr. the following degrees B. on scale for liquids lighter than water;—(a.) 18°B.; (b.) 30°B.; (c.) 40°B.; (d.) 50°B.

ANSWERS.

1. (a.) 1.00; (b.) 1.2; (c.) 1.26. 2. (a.) .946; (b.) .874.

CALCULATING DOSES FOR CHILDREN.

The rule most generally employed is known as Dr. Young's Rule, and is as follows:

Multiply the adult dose by the fraction obtained by dividing the age of the child [in years] by its age plus 12.

Problem.—If the adult dose of the medicine is 5 gr., what is the dose for a child 4 years old?

Calculation— $4 \div (4 + 12) = \frac{4}{16} = \frac{1}{4}$.

Then 5 gr. $\times \frac{1}{4} = \frac{5}{4} = 1\frac{1}{4}$ gr.

Problem.—The adult dose of a certain medicine is $\frac{1}{8}$ gr. How much should be given to a child 2 years old?

Calculation.— $2 \div (2 + 12) = \frac{2}{14} = \frac{1}{7}$

Then $\frac{1}{8}$ gr. $\times \frac{1}{7} = \frac{1}{56}$ gr.

Note.—Children are very susceptible to narcotics, especially to opium; and of these medicines less than one-half the amount indicated by Young's Rule is usually given. Of cathartics, however, double the calculated dose is generally required.

REFERENCE TABLES.

VOLUME AND WEIGHT.*

A. Volume to Weight.

1. Cubic Centimeters to Grammes.
   no. of c.c. given × sp. gr. = wt. in Gm.
2. Fluid Ounces to Grains.
   (454.6 × sp. gr.) × no. of f ℥ given = wt. in gr.
3. Minims to Grains.
   (.95 gr. × sp. gr.) × no. of ♏ given = wt. in gr.
4. Cubic Centimeters to Grains.
   (no. of c.c. given × sp. gr.) × 15.432 = wt. in gr.
5. Fluid Ounces to Grammes.
   (no. of f℥ given × 29.57) × sp. gr. = no. of Gm.

B. Weight to Volume.

1. Grammes to Cubic Centimeters.
   (no. of Gm. given ÷ sp. gr. = vol. in c.c.
2. Grains to Fluid Ounces.
   no. of gr. given ÷ (454.6 × sp. gr.) = vol. in f℥.
3. Grains to Minims.
   no. of gr. given ÷ (.95 gr. × sp. gr.) = vol. in ♏.
4. Grammes to Fluid Ounces
   (no. of Gm. given ÷ sp. gr.) ÷ 29.57 = vol. in f℥.
5. Grains to Cubic Centimeters
   (no. of gr. given × .0648) ÷ sp. gr. = no. of c.c.

VALUES WHICH ARE PROPORTIONAL.

Quantity (in wt. or vol.) to money value.
In weight-percentage. % to weights, but not to volumes.
In volume-percentage. % to volumes, but not to weights.
In $^{w}/_{v}$ solutions. (a.) gr. of constituent to ♏ of solution.
(b.) Gm. of constituent to c.c of solution.
In concentration and dilution . % inversely to wt. of solution.
In alligation problems. Proportionate parts to weights.
In chemical problems. atomic and molecular weights to actual weights.
In gasometric problems.
(a.) volumes of gases to their weights.
(b.) volume inversely to pressure.
(c.) volume directly to absolute temperature.
In figuring interests, profit and loss, discount, etc., % is directly proportional to money value.

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* Remember that a cubic centimeter is a mil.

Table of Atomic Weights

Element	Symbol	At. Wt. Based on O = 16	Approximate At. Wt.	Element	Symbol	At. Wt. Based on O = 16	Approximate At. Wt.
Aluminum...	Al	27.1	27	Lead	Pb	207.1	207
Antimony....	Sb	120.2	120	Lithium	Li	6.94	7
Arsenic..... .	As	74.96	75	Magnesium..	Mg	24.32	24
Barium........	Ba	137.37	137	Manganese...	Mn	54.93	55
Bismuth.....	Bi	208.0	208	Mercury......	Hg	200.6	200
Boron	B	11.0	11	Molybdenum	Mo	96.0	96
Bromin........	Br	79.92	80	Nickel..........	Ni	58.68	59
Cadmium.....	Cd	112.4	112	Nitrogen......	N	14.01	14
Calcium	Ca	40.07	40	Oxygen........	O	16.0	16
Carbon	C	12.0	12	Phosphorus..	P	31.04	31
Chlorin	Cl	35.46	35	Platinum	Pt	195.2	195
Chromium...	Cr	52.0	52	Potassium....	K	39.1	39
Cobalt.........	Co	58.97	59	Silicon.........	Si	28.3	28
Copper	Cu	63.57	64	Silver...........	Ag	107.88	108
Fluorin.......	F	19.0	19	Sodium........	Na	23.0	23
Gold	Au	197.2	197	Strontium....	Sr	87.63	88
Hydrogen ...	H	1.008	1	Sulphur	S	32.07	32
Iodin...........	I	126.92	127	Tin..............	Sn	119.0	119
Iron............	Fe	55.82	56	Zinc.............	Zn	65.37	65

APPENDIX

Nearly sixty-five per cent. of all the problems in the book are "answered" in the text. It has been thought best to supply in this appendix an additional list of answers, some "approximate."

CHAPTER I

No. 21: 9.36 Gm., 5.76 Gm., 7.2 Gm.; No. 55: 6 fl. ℥; No. 74: 145+.

CHAPTER II

No. 13: ⅛ inch smaller; No. 49 (b): 5.41 mg.; No. 54: 56.7 Gm., 56.7 Gm., 28.35 Gm., 425.25 Gm.

CHAPTER III

No. 10: Sp. gr., .908; No. 40: 175.7 c.c.; No. 42: 258.6 c.c.; No. 47: 101.25 c.c.; No. 51: 1.14 fl. ℥; No. 53: 4.4 fl. ℥; No. 54: 3.43 pts.; No. 63: 21.5¢.

CHAPTER V

No. 4 (b) 1.86¢, (c) 4.67¢, (d) 4.3¢; No. 7: $5.25; No. 8 (a): 63.4¢, (b) 14¢, (c) 71¢, (d) 41.6 gal.; No. 16: $21.84.

CHAPTER VI

No. 6: 18%; No. 11: 8,000 Gm.; No. 13: 1.2%; No. 15: 36.36%; No. 17: 5.88%; No. 24: .96 oz. and 31.04 oz.; No. 25: 3996 Gm.; No. 31: 113.5 Gm.; No. 32: 292.2 Gm.; No. 37 (b): 3378 Gm.; No. 38: 42.5%; No. 40: 26.85%; No. 53: 1.05 Gm. of apomorphine; No. 54: 3.83 Gm. cocaine.

CHAPTER VII

No. 8: 2219.5 Gm., No. 9: 2399.71 Gm.; No. 10: 3.45 lb.; No. 14: 716.25 Gm.; No. 21: 4.44 Gm.; No. 22: 2.5 Gm.

CHAPTER VIII

No. 14: 84 parts abs., 40 parts 36%, 40 parts water; No. 19: 125 Gm.; No. 20: 1000 c.c.; No. 27: 15.3+ gr. and 484.6+ gr.

CHAPTER IX

No. 7: 59.85%; No. 9: 75%; No. 12: 69.8%; No. 14: 45.3%; No. 18: 43+ Gm.; No. 21: 22.5 Gm.; No. 28: 64.9 Gm. of KI and 59.2 Gm. of tartaric acid; No. 41: 4 oz; No. 45: 409 c.c.

CHAPTER X

No. 3: 699.78 L. of oxygen, 25.4 L. of CO_2; No. 4: 143.5 Gm. of SO_2.

SEE NEXT PAGE